1972 YEARBOOK OF ASTRONOMY

EDITED BY
PATRICK MOORE

1972 Yearbook of Astronomy

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PATRICK MOORE

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Editorial

The present *Yearbook* follows the established pattern, with notes for 1972, articles of all kinds, and the usual 'miscellanea'. Again Dr J. G. Porter's contributions have been invaluable, and it is he who has provided all of Part I apart from the monthly comments. Dr Porter relinquished the Editorship of the *Yearbooks* seven years ago, but without his continued help it would be difficult or even impossible to maintain the standard that he set.

Thanks are due to all our contributors, some of whom have written for us before while others are presenting their first articles. Lawrence Clarke has provided the line drawings, as on previous occasions.

Last but by no means least, I must again express my most sincere thanks to J. S. Knapp-Fisher and his colleagues at Messrs Sidgwick and Jackson; and, for the American edition, equally to Eric Swenson and all those at Messrs W. W. Norton and Co.

PATRICK MOORE

Selsey, 1971

Preface

New readers will find that all the information in this *Yearbook* is given in diagrammatic or descriptive form; the positions of the planets may easily be found on the specially designed star charts, while the monthly notes describe the movements of the planets, and give details of other astronomical phenomena that may be observed from these latitudes. The reader who needs more detailed information will find *Norton's Star Atlas* (Gall and Inglis, £1.25) invaluable, while more precise positions of the planets and their satellites, together with predictions of occultations, meteor showers and periodic comets may be found in the *Handbook* of the British Astronomical Association. A somewhat similar publication is the *Observer's Handbook* of the Royal Astronomical Society of Canada, and readers will also find details of forthcoming events given in the American *Sky and Telescope* (which also publishes complete details of all occultations visible in North America and in the British periodical *Astronomy and Space*)

Important Note

The star charts are drawn, and the notes are, in general, designed for use in latitude 52 degrees north, but may be used without alteration throughout the British Isles, and (except in the case of eclipses and occultations) in other countries of similar north latitude.

The times given on the star charts and in the Monthly Notes are generally given as local times, using the 24-hour clock, the day beginning at midnight. Ignoring small differences of longitude, this local time may be taken as Greenwich Mean Time

(G.M.T.) in the British Isles, or as the appropriate Standard Time in other Time Zones. If Summer Time is in use, the clocks will have been advanced by one hour, and this hour must be subtracted from the clock time to give local time.

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PART ONE

Events of 1972

Monthly Charts and Astronomical Phenomena

Notes on the Star Charts

The stars, together with the Sun, Moon and planets, seem to be set on the surface of the celestial sphere, which appears to rotate about the Earth from east to west. Since it is impossible to represent a curved surface accurately on a plane, any kind of star map is bound to contain some form of distortion. But it is well known that the eye can endure some kinds of distortion better than others, and it is particularly true that the eye is most sensitive to deviations from the vertical and horizontal. For this reason the star charts given in this volume on pages 20 to 45 have been designed to give a true representation of vertical and horizontal lines, whatever may be the resulting distortion in the shape of a constellation figure. It will be found that the amount of distortion is, in general, quite small, and is only obvious in the case of large constellations such as Leo and Pegasus, when these appear at the top of the charts, and so are drawn out sideways.

The charts show all stars down to the fourth magnitude, together with a number of fainter stars which are necessary to define the shape of a constellation. There is no standard system for representing the outlines of the constellations, and triangles and other simple figures have been used to give outlines which are easy to follow with the naked eye. The names of the constellations are given, together with the proper names of the brighter stars. The apparent magnitudes of the stars are indicated roughly by using four different sizes of dots, the larger dots representing the bright stars.

There are four such charts at each opening, and these give a complete coverage of the sky up to an altitude of 62½ degrees; there are twelve such sets to cover the entire year. The upper two charts show the southern sky, south being at the centre; the coverage is 200 degrees in azimuth, from a little north of east (top left) to a little north of west (top right). The two lower charts show the northern sky, from a little south of west (lower left) to a little south of east (lower right). There is thus an overlap east and west.

The charts have been drawn for a latitude of 52 degrees, but may be taken without appreciable error to apply to all parts of the British Isles. They will also be equally suitable for any other part of the world having a north latitude of about 52 degrees—e.g. parts of Europe and Asia, and Canada. In such cases the times given must be taken as local time, and not G.M.T., which applies only to the British Isles.

Because the sidereal day is shorter than the solar day, the stars appear to rise and set about four minutes earlier each day, which amounts to two hours in a month. Hence, the twelve sets of charts are sufficient to give the appearance of the sky throughout the day at intervals of two hours, or at the same time of night at monthly intervals throughout the year. The actual range of dates and times when the stars on the charts are visible is indicated at the top of each page. This information is summarized in the following table, which gives the number of the star chart to be used for any given month and time.

G.M.T.	16^{h}	18^{h}	20^{h}	22^{h}	0^{h}	2^{h}	4^{h}	6^{h}
January	10	11	12	1	2	3	4	5
February		12	1	2	3	4	5	6
March			2	3	4	5	6	
April			3	4	5	6		
May			4	5	6	7		
June			5	6	7			
July			6	7	8	9		
August			7	8	9	10	11	
September		7	8	9	10	11	12	
October		8	9	10	11	12	1	
November	8	9	10	11	12	1	2	3
December	9	10	11	12	1	2	3	4

The charts are drawn to scale, and estimates of altitude and azimuth may be made from them. These values will necessarily be mere approximations, since no observer will be exactly on the meridian of Greenwich at 52 degrees latitude, but they will generally serve for the identification of stars and planets. The horizontal measurements, marked at every ten degrees, give the azimuths (or true bearings) measured from the north round through east (90 degrees), south (180 degrees), and west (270 degrees). The vertical measurements, similarly marked, give the altitudes of the stars up to 62½ degrees.

The ecliptic is drawn as a broken line on which the longitude is marked at every ten degrees; the positions of the planets at any time are then easily found by reference to the table immediately following the star charts on page 46.

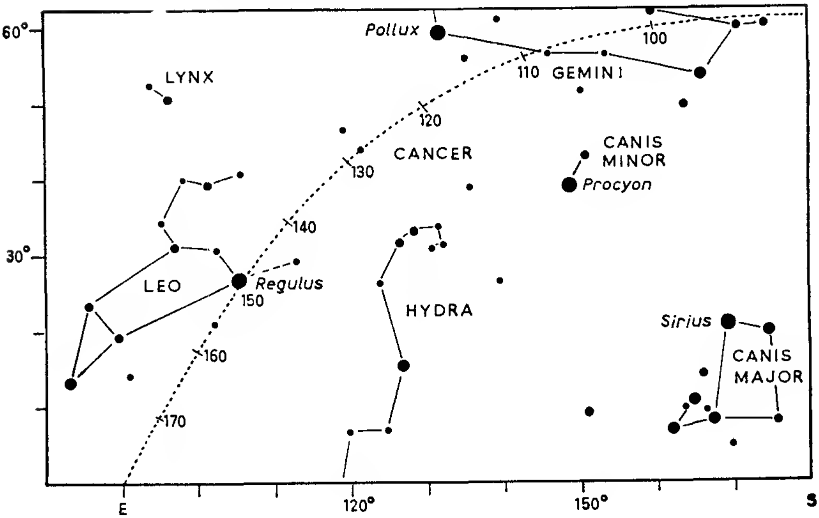
There is a curious illusion that stars at an altitude of 60 degrees or more are actually overhead, and the beginner may often feel that he is leaning over backwards in trying to see them. These high-altitude stars, being nearer the pole, move more slowly across the sky, and a different kind of map may therefore be used. These overhead stars are given separately on pages 44 and 45, the entire year being covered at one opening. Each of the four maps shows the overhead stars at times which correspond to those of three of the main star charts. The position of the zenith in latitude 52 degrees is indicated by a cross, and this cross also marks the centre of a circle which is 35 degrees from the zenith, and which therefore indicates an altitude of 55 degrees; there is thus a small overlap with the main charts.

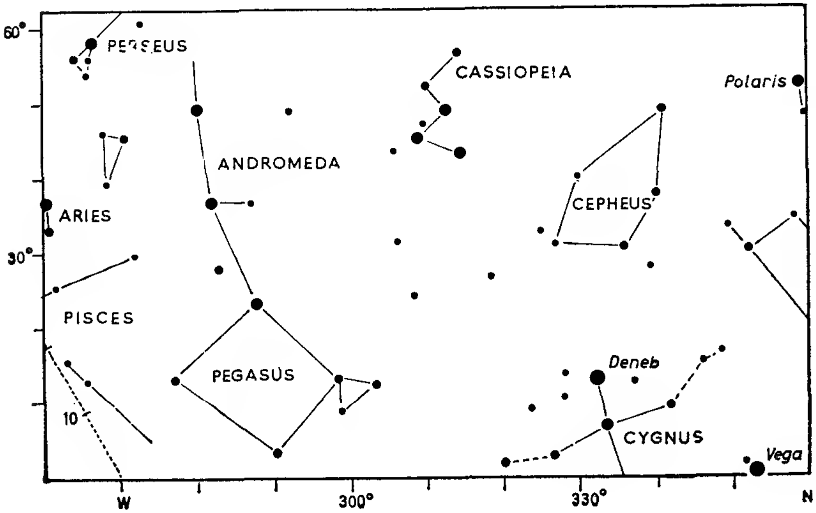
The broken line leading from north to south is numbered to indicate the corresponding main chart. Thus on page 44 the N–S line numbered 6 is to be regarded as an extension of the S line of chart 6 on pages 30 and 31, and at the top of these pages are given dates and times which are appropriate.

The scale is the same on all the charts (approximately 25 degrees to the inch), but the overhead stars are plotted as a true map on a conical projection, and are not simple graphs like the main charts.

1L

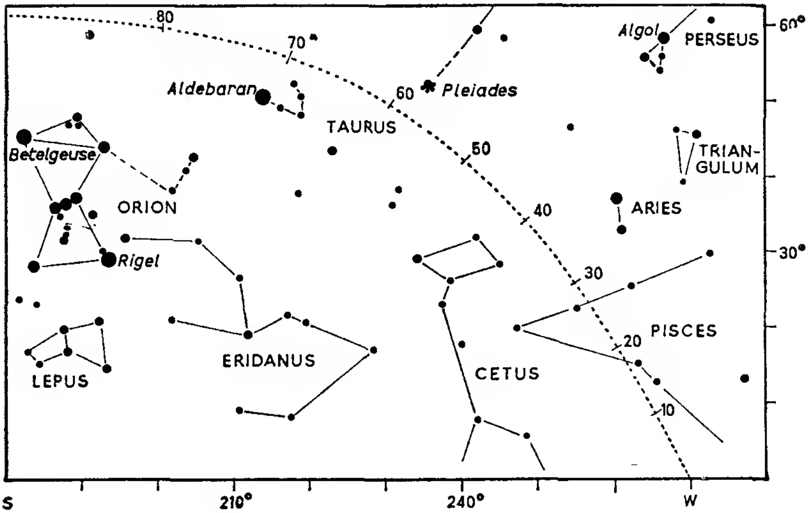
October 6 at 5^h	October 21 at 4^h
November 6 at 3^h	November 21 at 2^h
December 6 at 1^h	December 21 at midnight
January 6 at 23^h	January 21 at 22^h
February 6 at 21^h	February 21 at 20^h

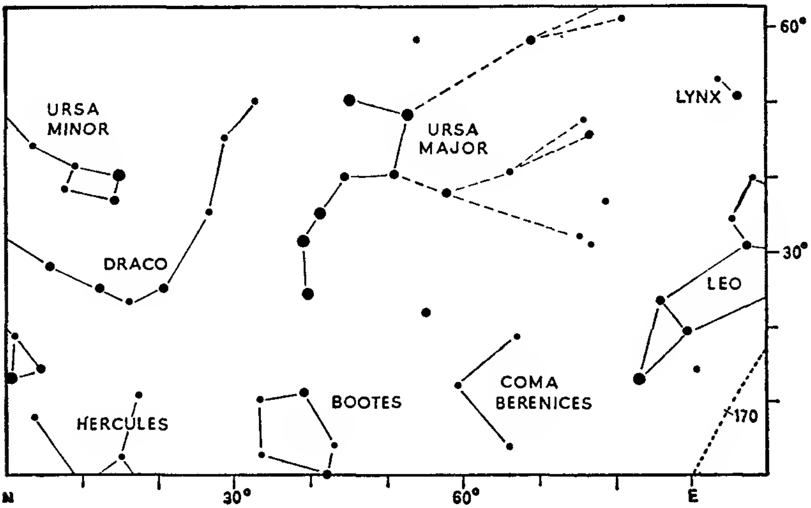




October 6 at	5^h	October 21 at	4^h
November 6 at	3^h	November 21 at	2^h
December 6 at	1^h	December 21 at	midnight
January 6 at	23^h	January 21 at	22^h
February 6 at	21^h	February 21 at	20^h

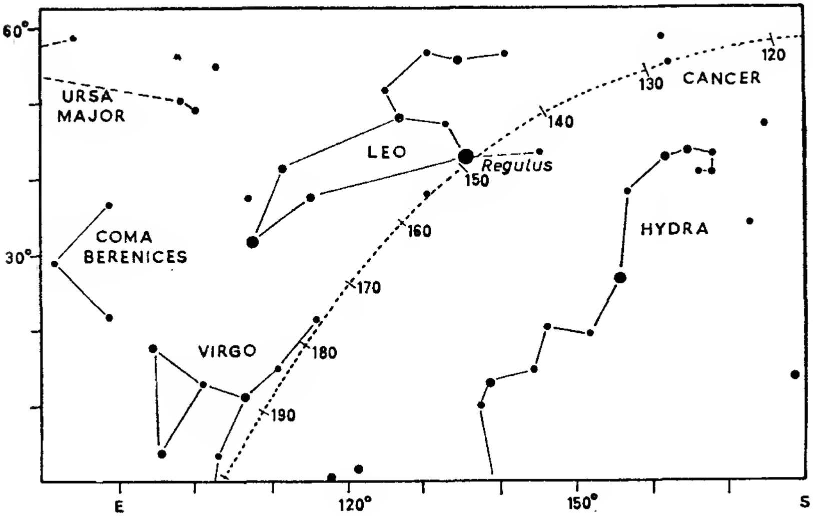
1R

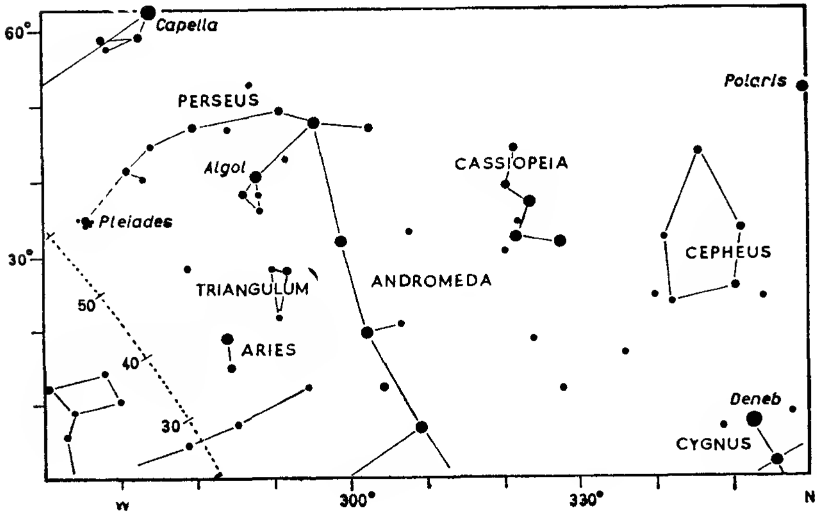




2L

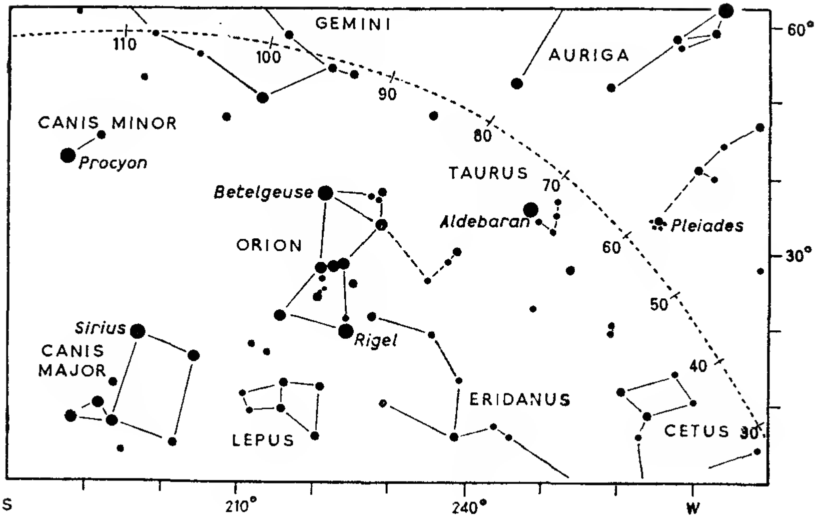
November 6 at 5h	November 21 at 4h
December 6 at 3h	December 21 at 2h
January 6 at 1h	January 21 at midnight
February 6 at 23h	February 21 at 22h
March 6 at 21h	March 21 at 20h

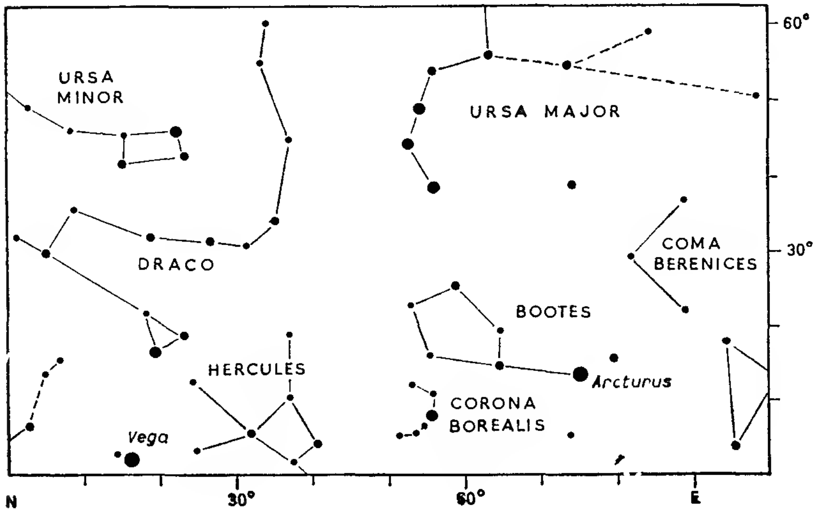




November 6 at 5^h	November 21 at 4^h
December 6 at 3^h	December 21 at 2^h
January 6 at 1^h	January 21 at midnight
February 6 at 23^h	February 21 at 22^h
March 6 at 21^h	March 21 at 20^h

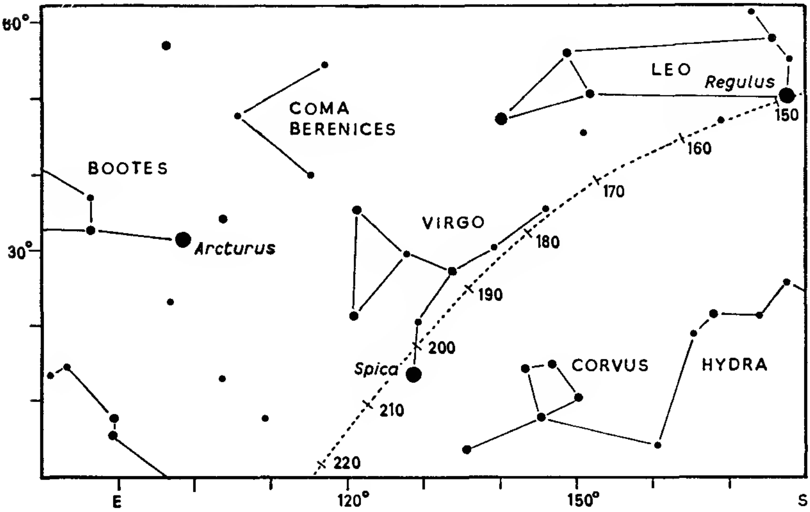
2R

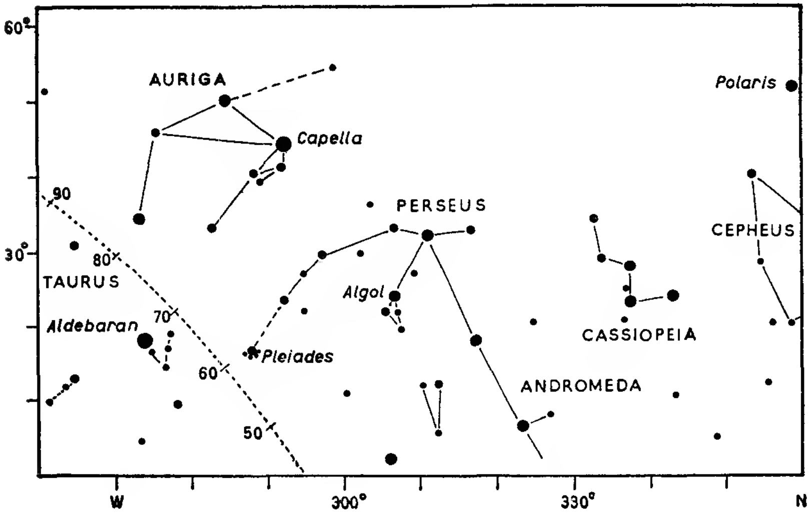




3L

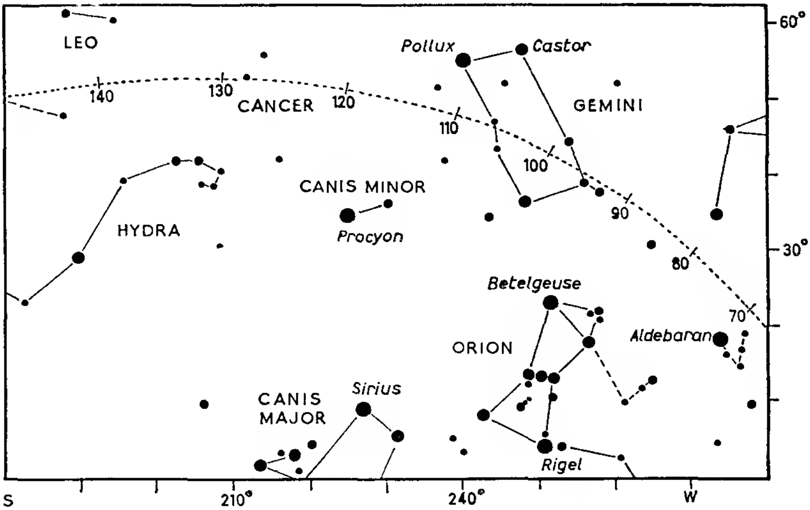
December 6 at 5^h	December 21 at 4^h
January 6 at 3^h	January 21 at 2^h
February 6 at 1^h	February 21 at midnight
March 6 at 23^h	March 21 at 22^h
April 6 at 21^h	April 21 at 20^h

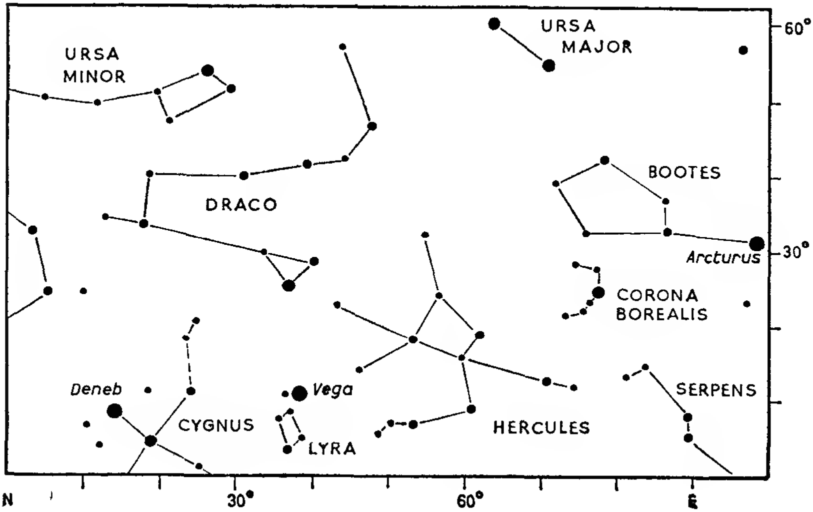




December 6 at 5h	December 21 at 4h
January 6 at 3h	January 21 at 2h
February 6 at 1h	February 21 at midnight
March 6 at 23h	March 21 at 22h
April 6 at 21h	April 21 at 20h

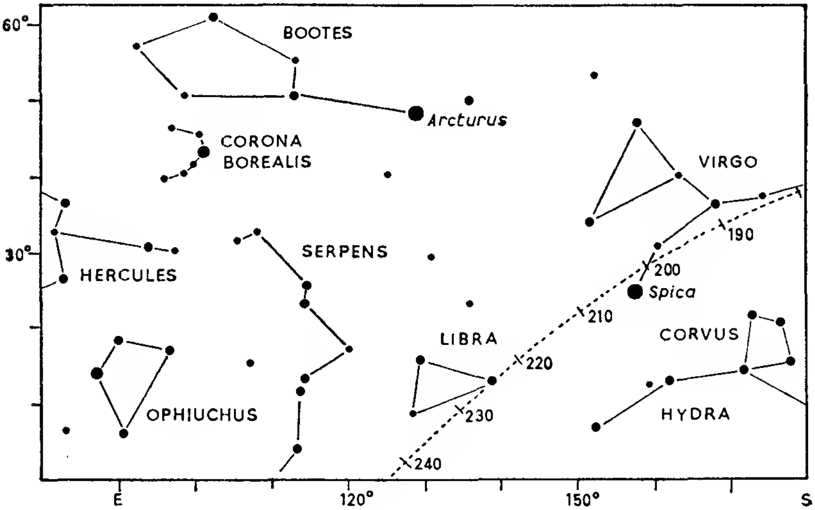
3R

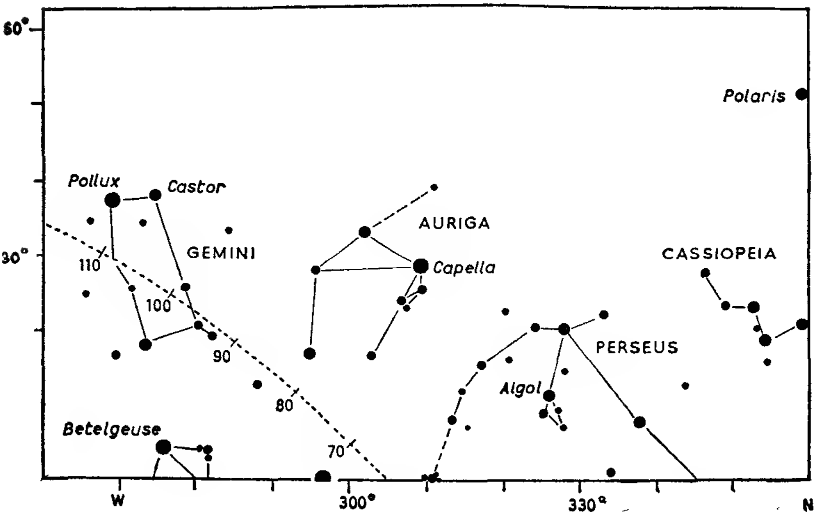




4L

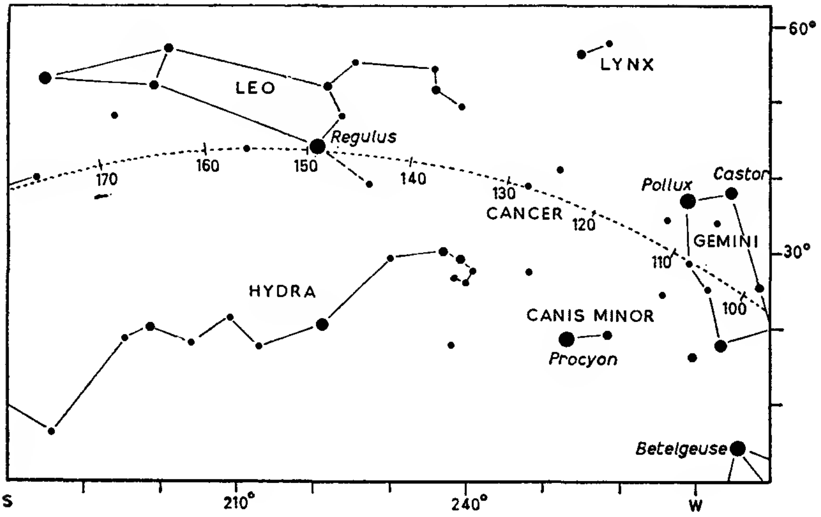
January 6 at	5^h	January 21 at	4^h
February 6 at	3^h	February 21 at	2^h
March 6 at	1^h	March 21 at	midnight
April 6 at	23^h	April 21 at	22^h
May 6 at	21^h	May 21 at	20^h

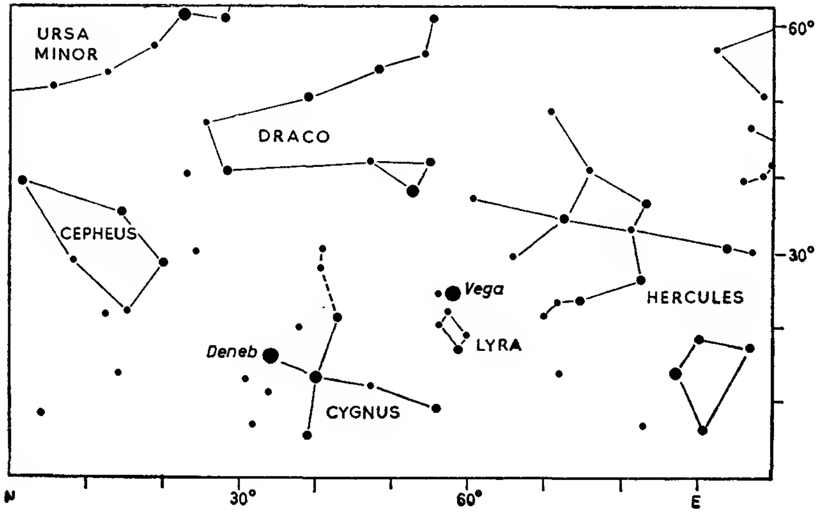




January 6 at 5^{h}	January 21 at 4^{h}
February 6 at 3^{h}	February 21 at 2^{h}
March 6 at 1^{h}	March 21 at midnight
April 6 at 23^{h}	April 21 at 22^{h}
May 6 at 21^{h}	May 21 at 20^{h}

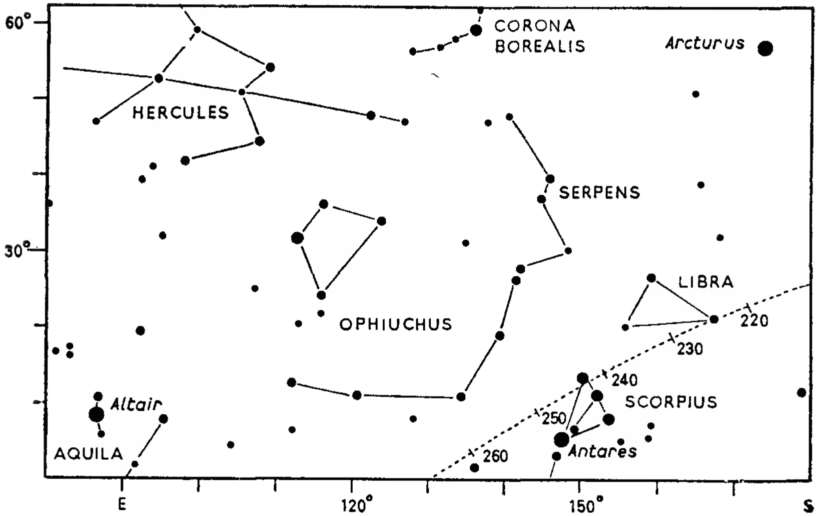
4R

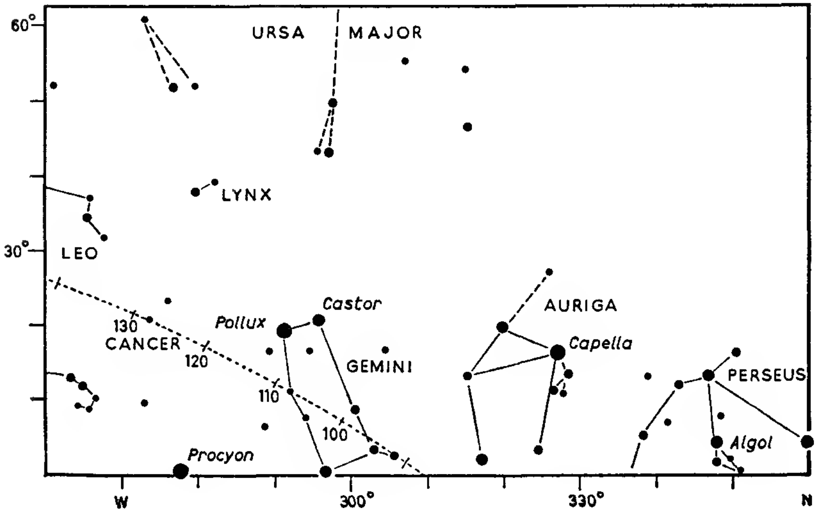




5L

January 6 at 7ʰ	January 21 at 6ʰ
February 6 at 5ʰ	February 21 at 4ʰ
March 6 at 3ʰ	March 21 at 2ʰ
April 6 at 1ʰ	April 21 at midnight
May 6 at 23ʰ	May 21 at 22ʰ

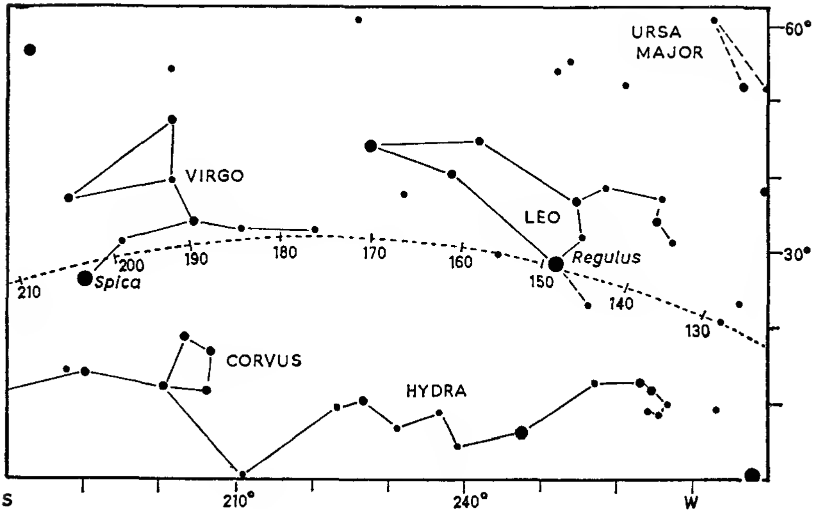


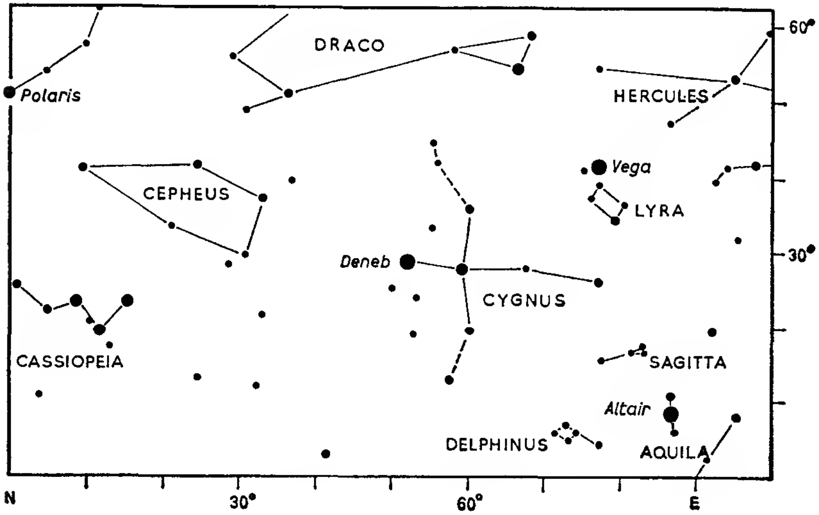


January 6 at 7ʰ
February 6 at 5ʰ
March 6 at 3ʰ
April 6 at 1ʰ
May 6 at 23ʰ

January 21 at 6ʰ
February 21 at 4ʰ
March 21 at 2ʰ
April 21 at midnight
May 21 at 22ʰ

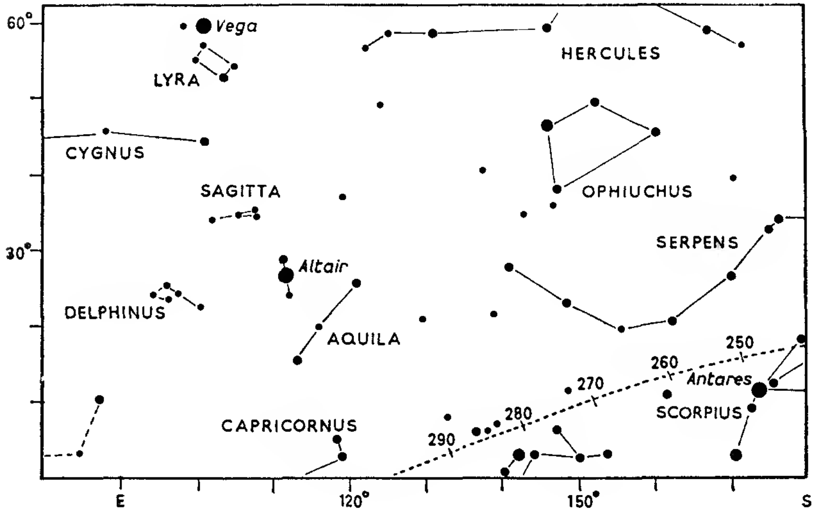
5R

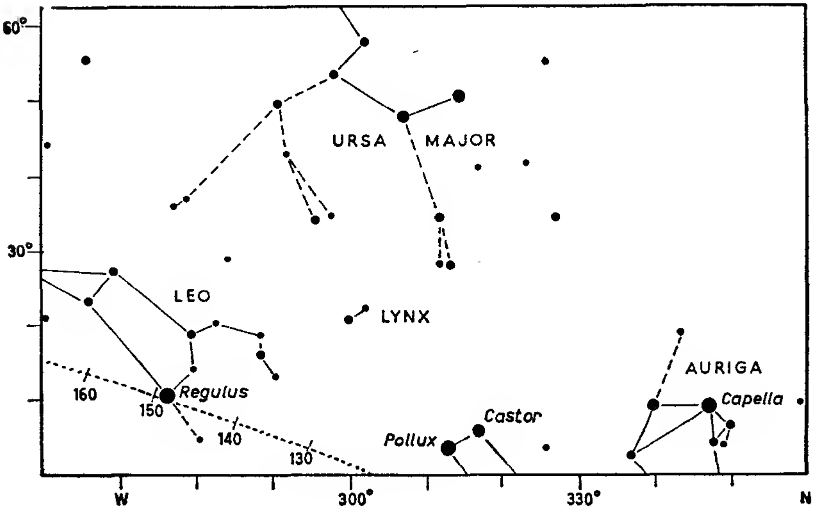




6L

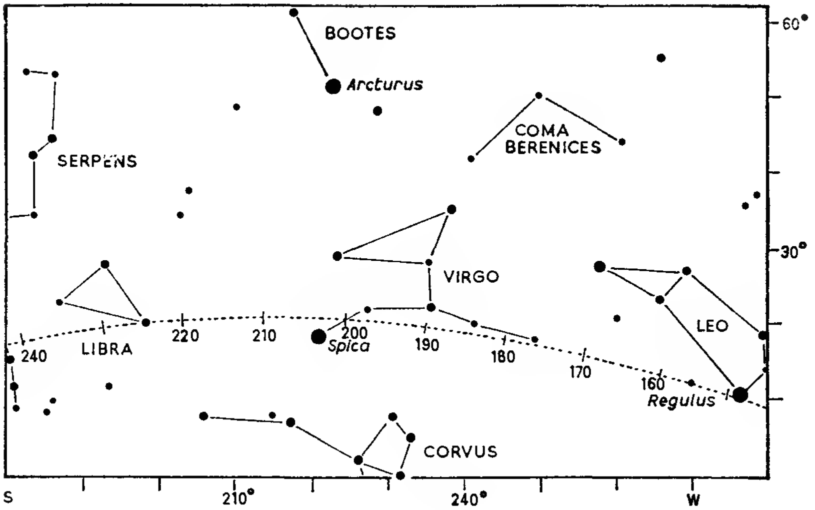
March 6 at 5^h	March 21 at 4^h
April 6 at 3^h	April 21 at 2^h
May 6 at 1^h	May 21 at midnight
June 6 at 23^h	June 21 at 22^h
July 6 at 21^h	July 21 at 20^h

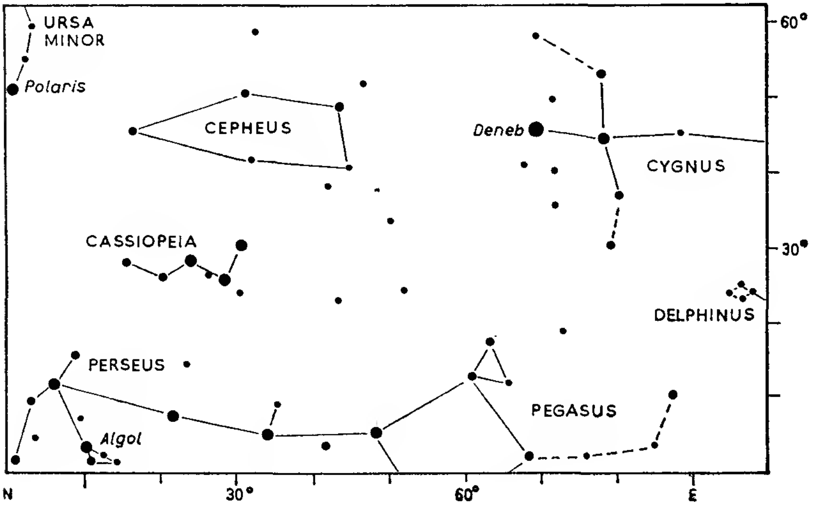




March 6 at 5^h	March 21 at 4^h
April 6 at 3^h	April 21 at 2^h
May 6 at 1^h	May 21 at midnight
June 6 at 23^h	June 21 at 22^h
July 6 at 21^h	July 21 at 20^h

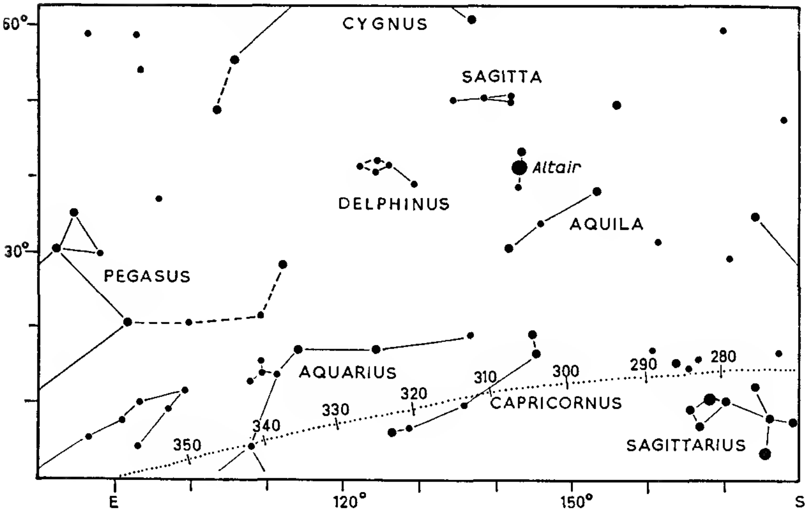
6R

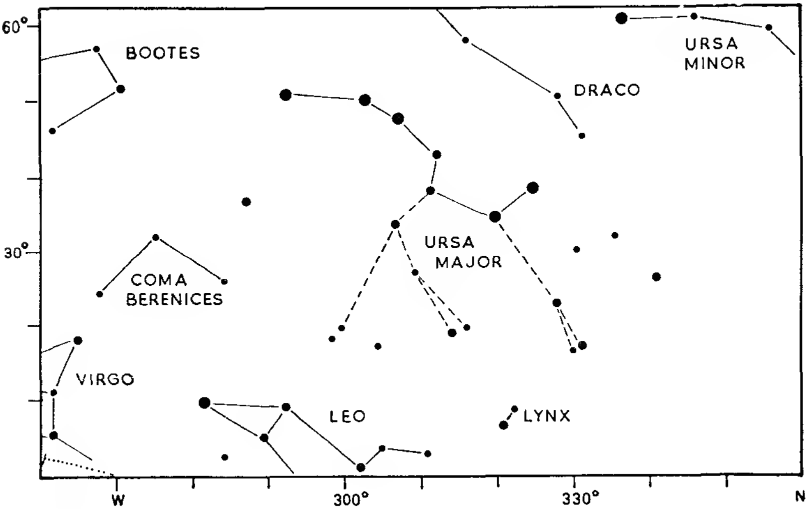




7L

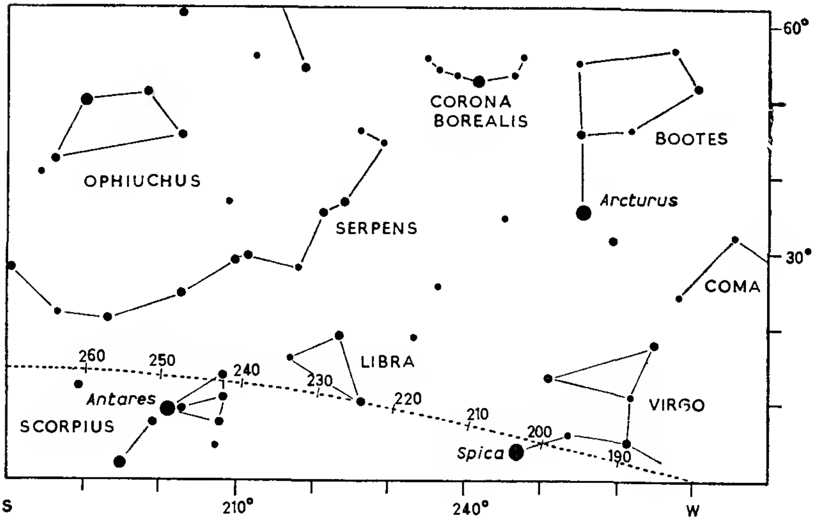
May 6 at 3h	May 21 at 2h
June 6 at 1h	June 21 at midnight
July 6 at 23h	July 21 at 22h
August 6 at 21h	August 21 at 20h
September 6 at 19h	September 21 at 18h

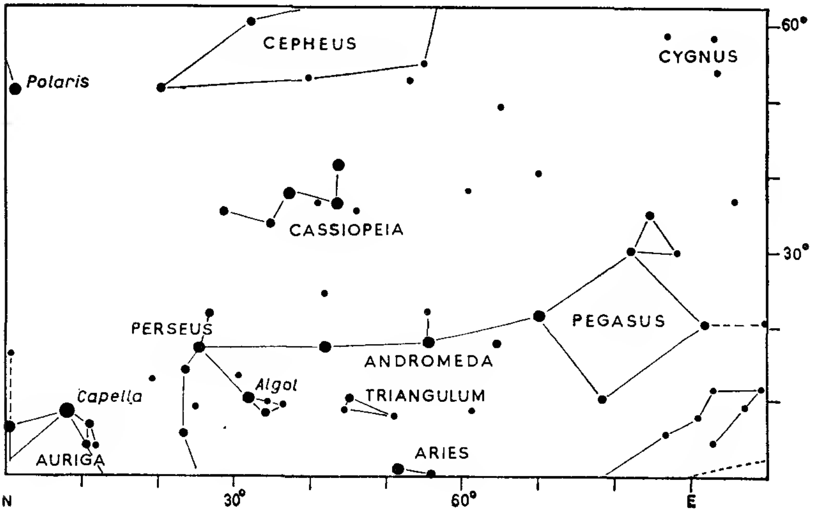




May 6 at 3h	May 21 at 2h
June 6 at 1h	June 21 at midnight
July 6 at 23h	July 21 at 22h
August 6 at 21h	August 21 at 20h
September 6 at 19h	September 21 at 18h

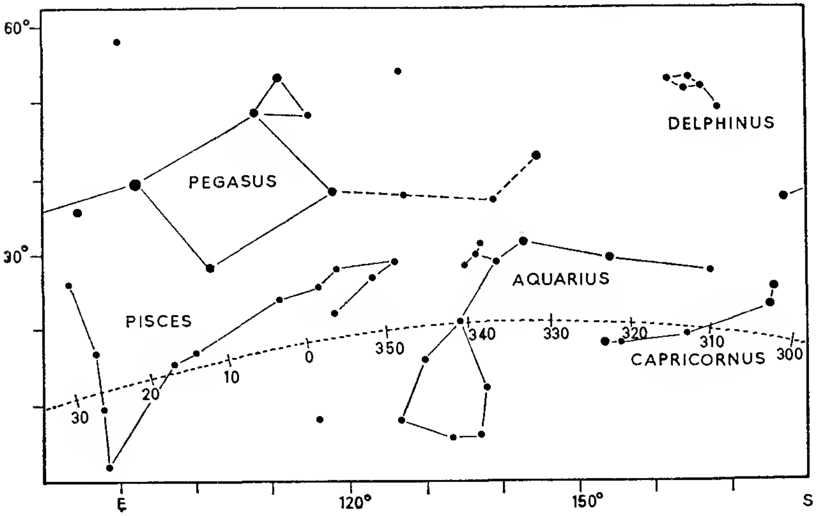
7R

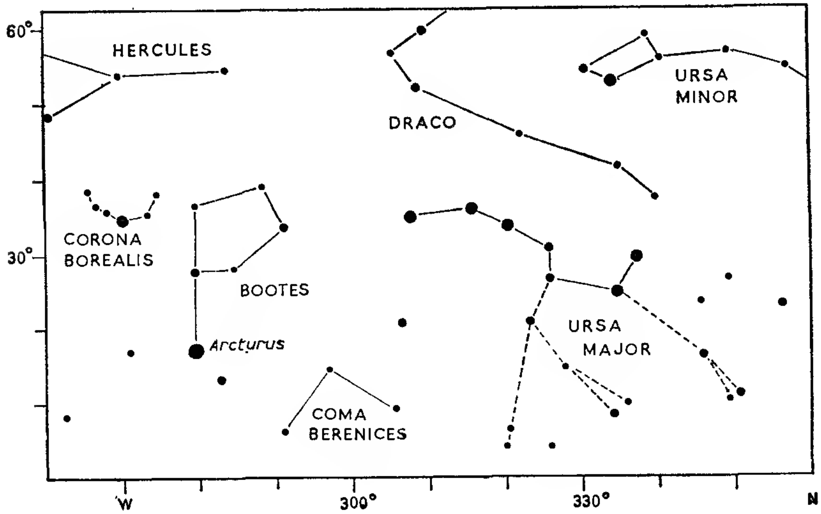




8L

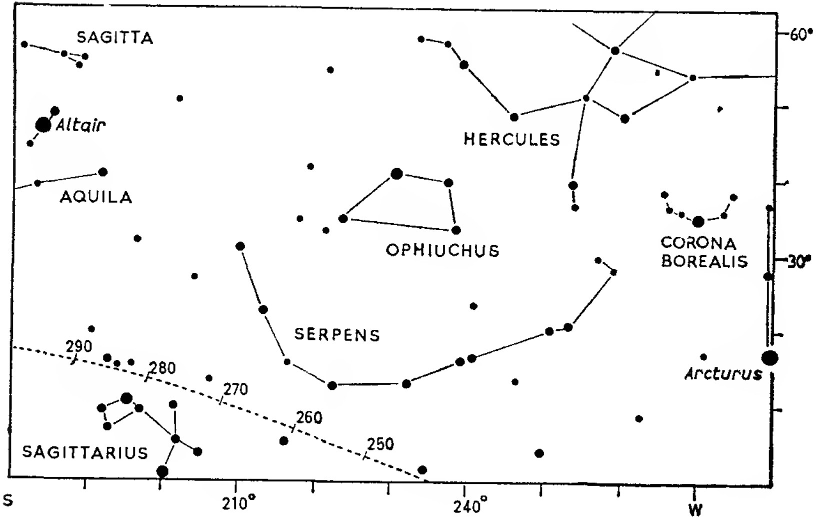
July 6 at 1^{h}	July 21 at midnight
August 6 at 23^{h}	August 21 at 22^{h}
September 6 at 21^{h}	September 21 at 20^{h}
October 6 at 19^{h}	October 21 at 18^{h}
November 6 at 17^{h}	November 21 at 16^{h}

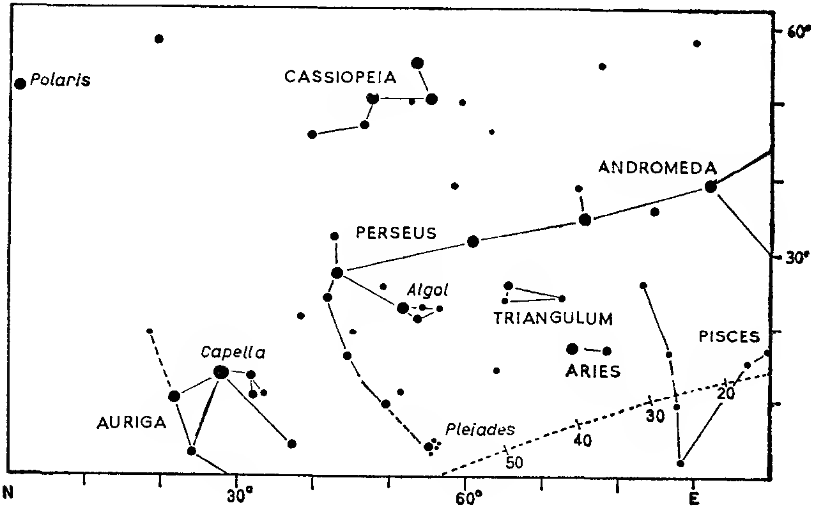




July 6 at 1^h	July 21 at midnight
August 6 at 23^h	August 21 at 22^h
September 6 at 21^h	September 21 at 20^h
October 6 at 19^h	October 21 at 18^h
November 6 at 17^h	November 21 at 16^h

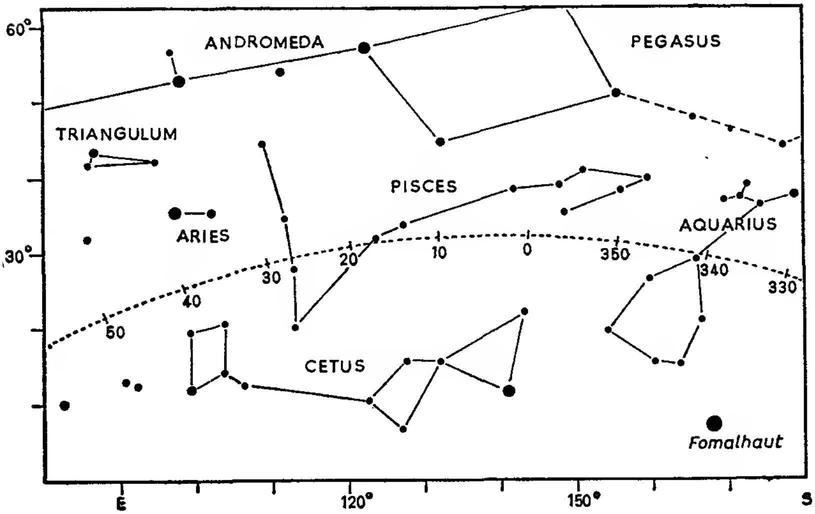
8R

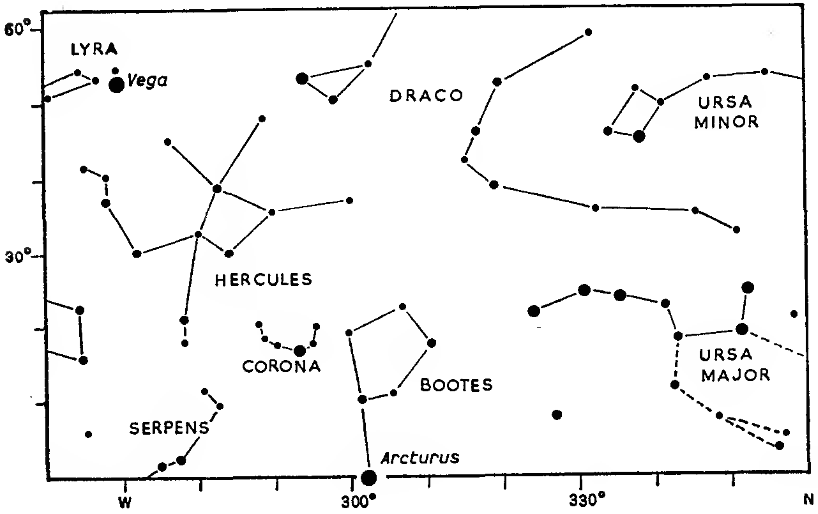




9L

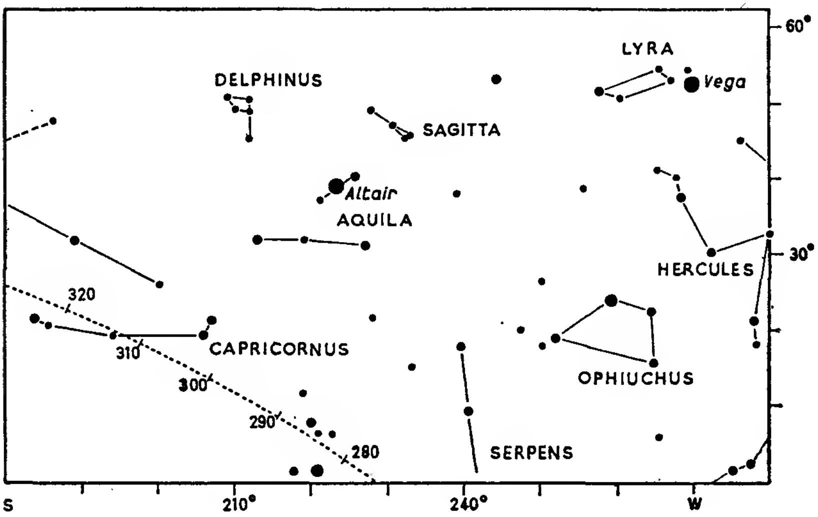
August 6 at 1^h	August 21 at midnight
September 6 at 23^h	September 21 at 22^h
October 6 at 21^h	October 21 at 20^h
November 6 at 19^h	November 21 at 18^h
December 6 at 17^h	December 21 at 16^h

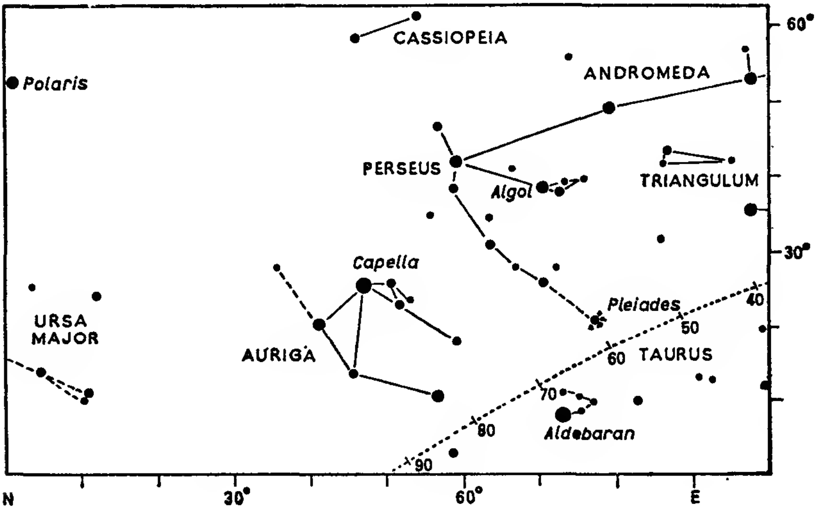




August 6 at 1^h	August 21 at midnight
September 6 at 23^h	September 21 at 22^h
October 6 at 21^h	October 21 at 20^h
November 6 at 19^h	November 21 at 18^h
December 6 at 17^h	December 21 at 16^h

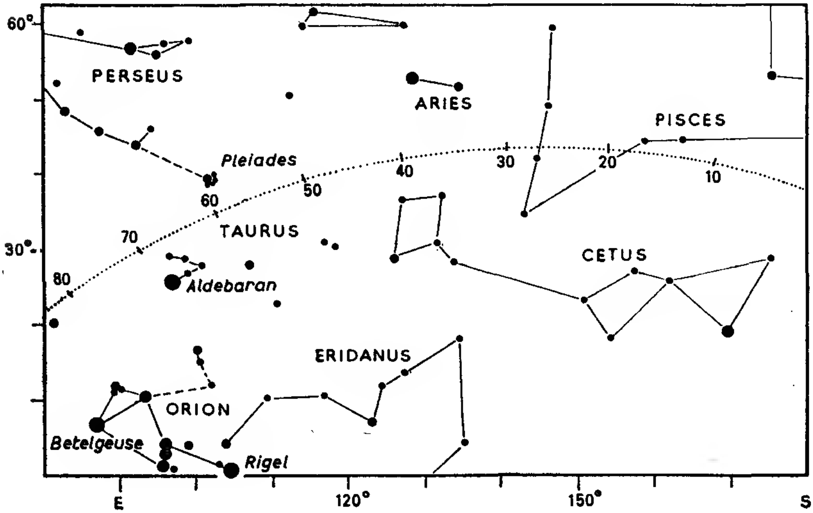
9R

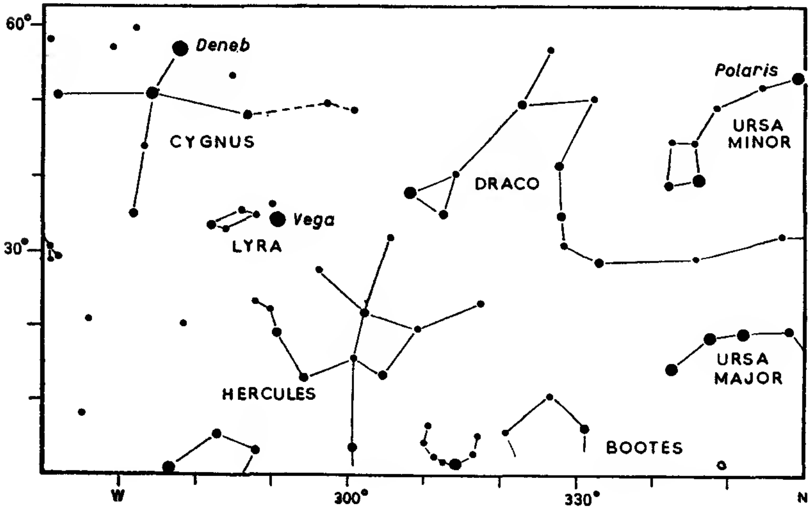




10L

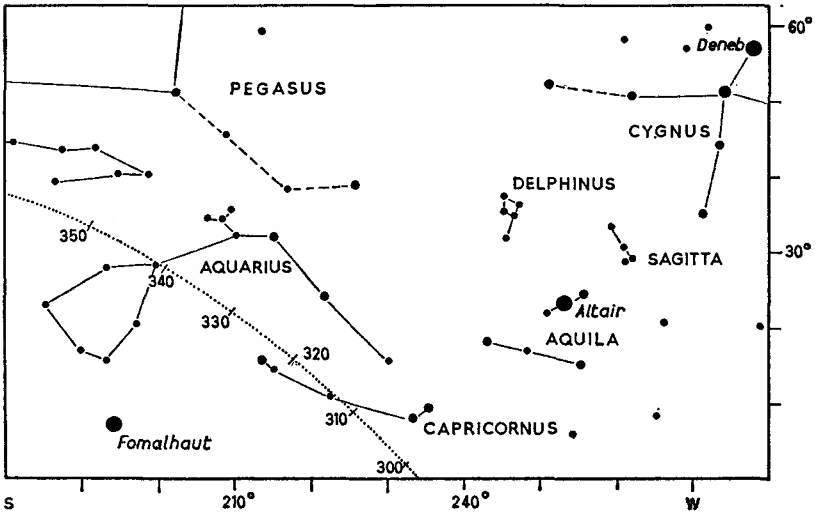
August 6	at 3h	August 21	at 2h
September 6	at 1h	September 21	at midnight
October 6	at 23h	October 21	at 22h
November 6	at 21h	November 21	at 20h
December 6	at 19h	December 21	at 18h

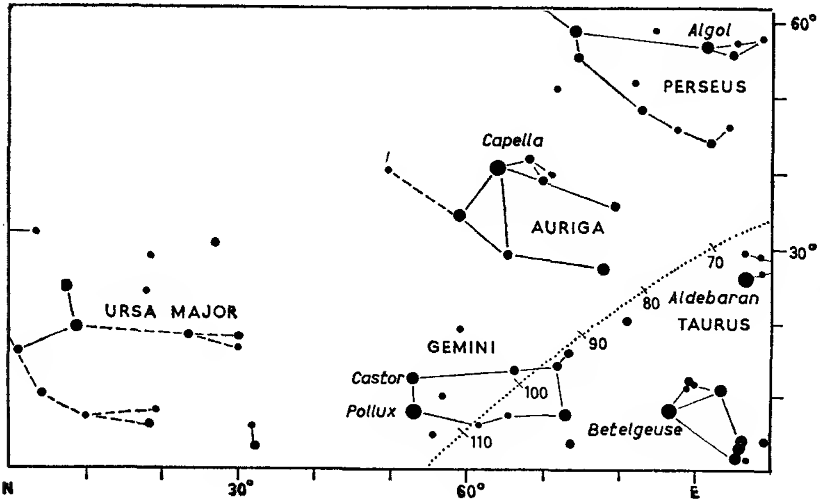




August 6 at 3^h	August 21 at 2^h
September 6 at 1^h	September 21 at midnight
October 6 at 23^h	October 21 at 22^h
November 6 at 21^h	November 21 at 20^h
December 6 at 19^h	December 21 at 18^h

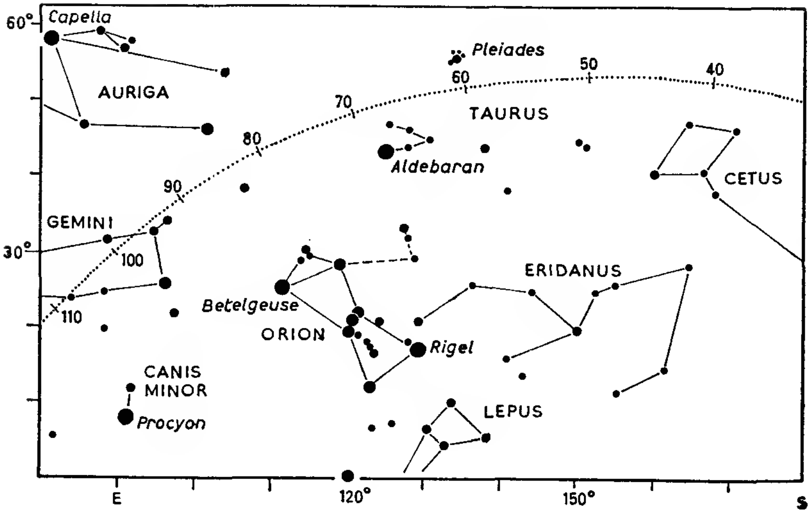
10R

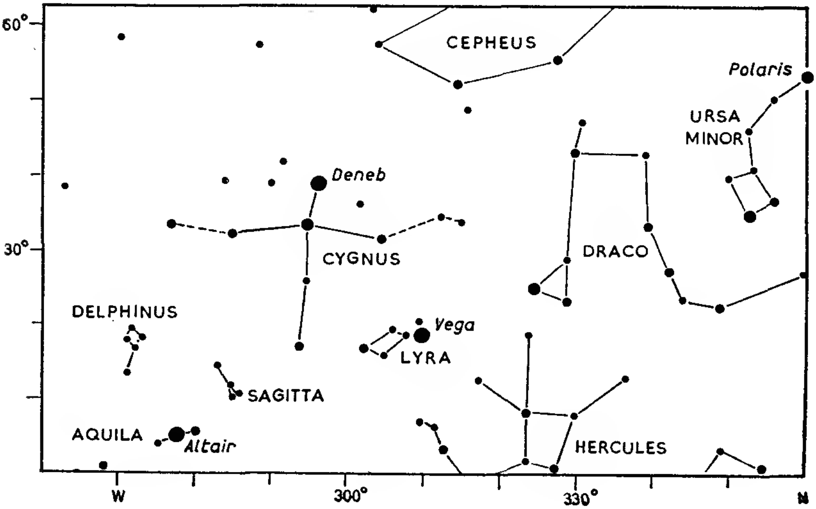




11L

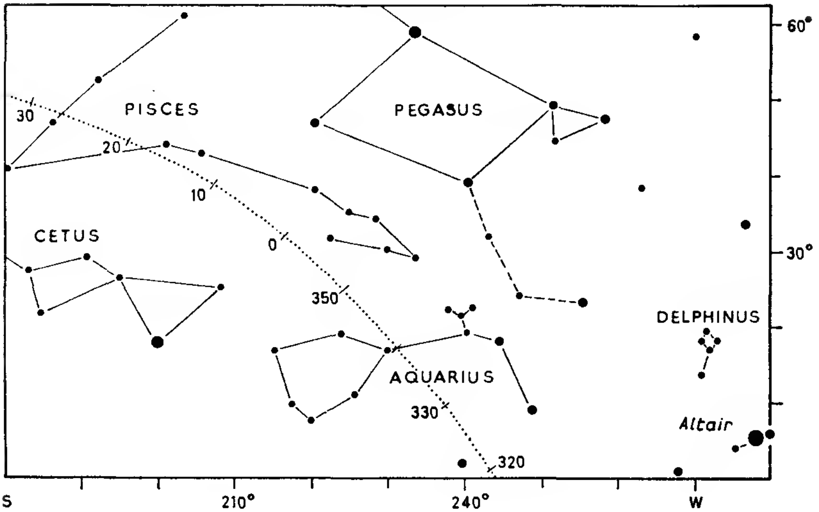
September 6 at	3h	September 21 at	2h
October 6 at	1h	October 21 at	midnight
November 6 at	23h	November 21 at	22h
December 6 at	21h	December 21 at	20h
January 6 at	19h	January 21 at	18h

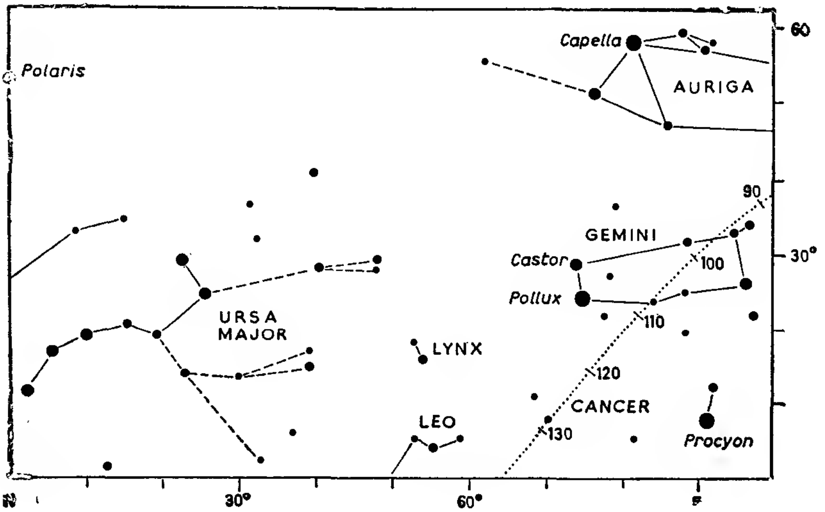




September 6 at	3^{h}	September 21 at	2^{h}
October 6 at	1^{h}	October 21 at	midnight
November 6 at	23^{h}	November 21 at	22^{h}
December 6 at	21^{h}	December 21 at	20^{h}
January 6 at	19^{h}	January 21 at	18^{h}

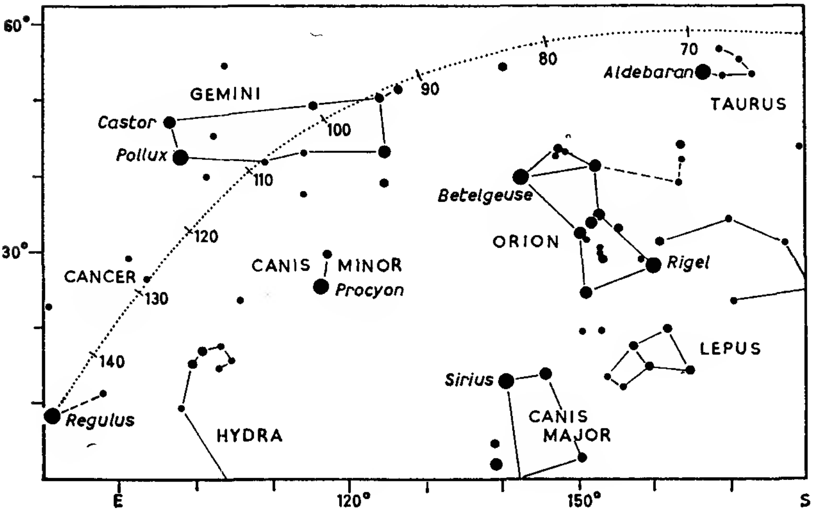
11R

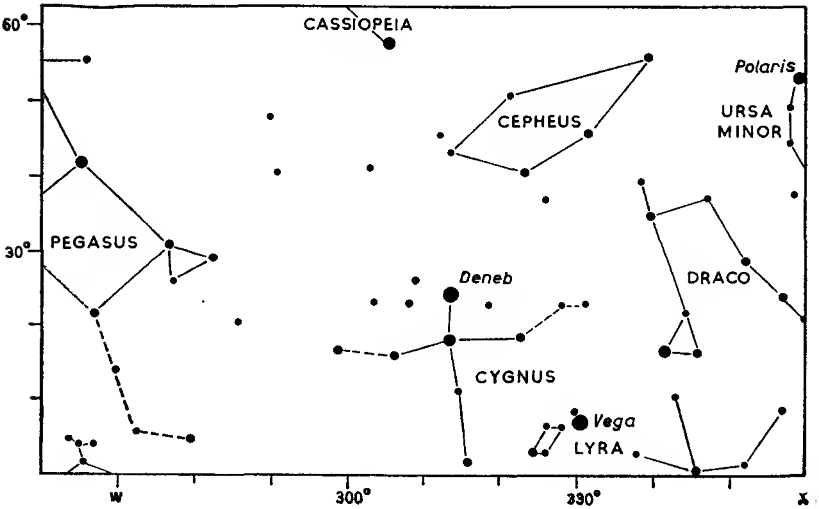




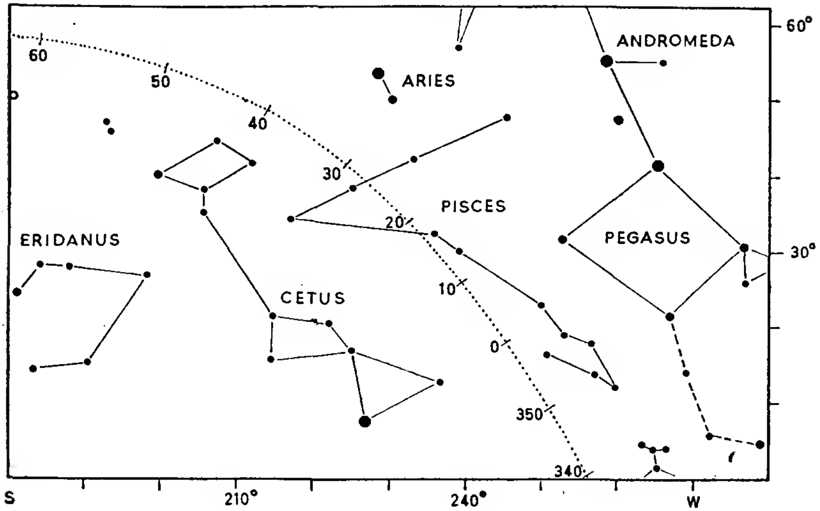
12L

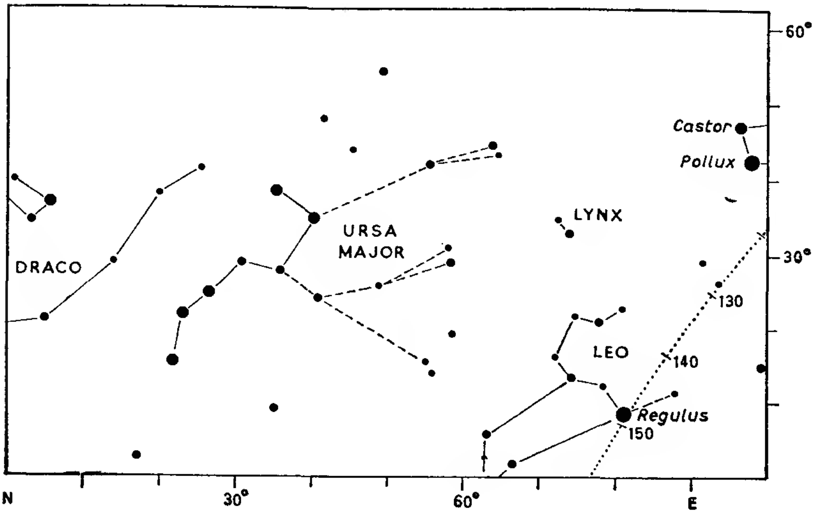
October 6 at	3^h	October 21 at	2^h
November 6 at	1^h	November 21 at	midnight
December 6 at	23^h	December 21 at	22^h
January 6 at	21^h	January 21 at	20^h
February 6 at	19^h	February 21 at	18^h

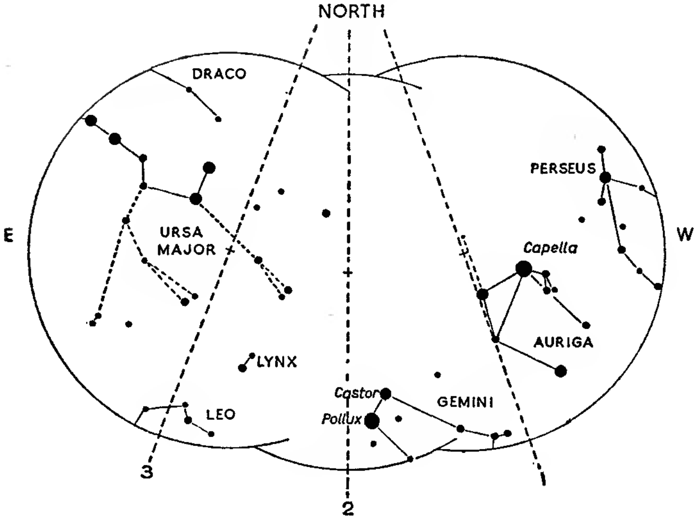


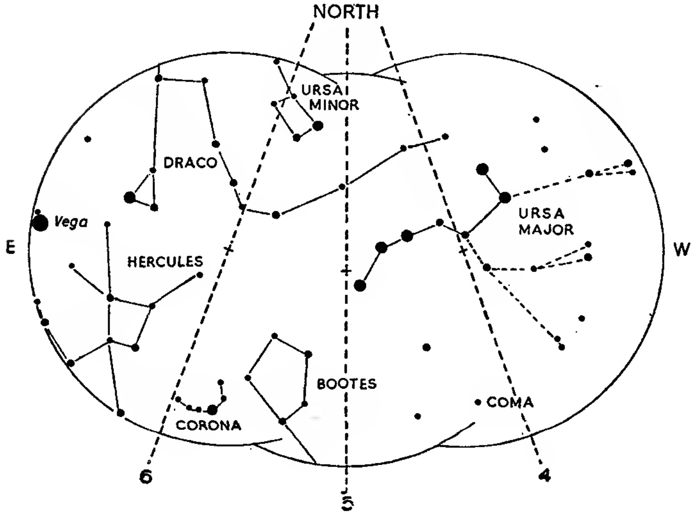


October	6 at	3^h	October	21	at	2^h	
November	6 at	1^h	November	21	at	midnight	**12R**
December	6 at	23^h	December	21	at	22^h	
January	6 at	21^h	January	21	at	20^h	
February	6 at	19^h	February	21	at	18^h	

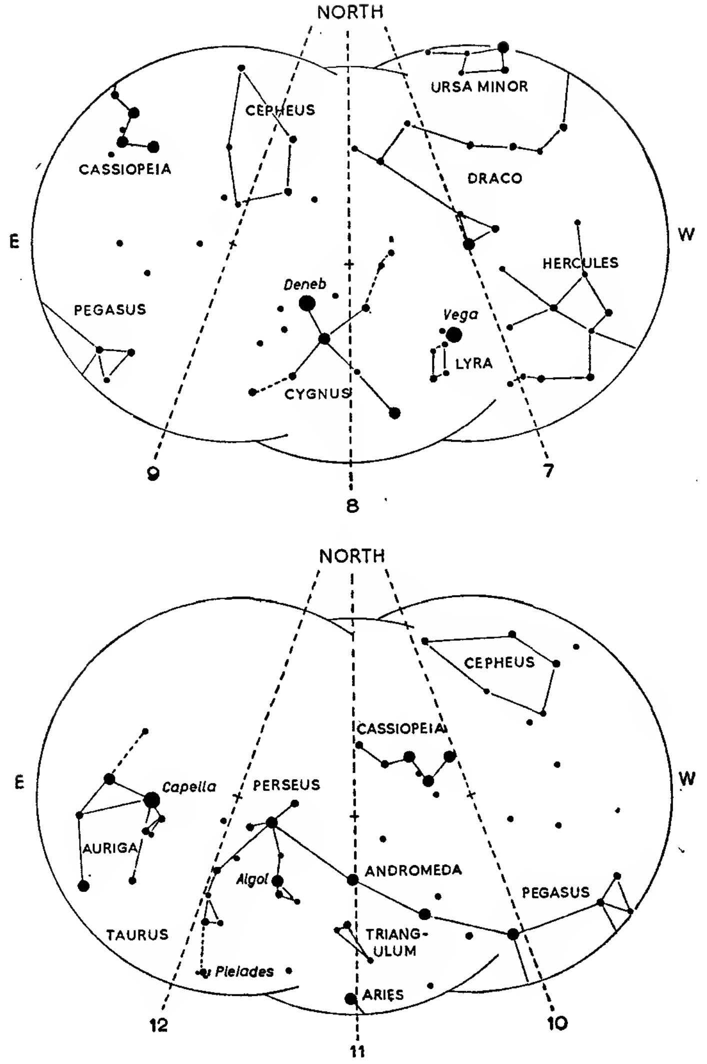








Overhead stars



Overhead stars

The Planets in 1972

DATE		*Venus*	*Mars*	*Jupiter*	*Saturn*	*Uranus*	*Neptune*
January	6	317°	7°	263°	61°	198°	245°
	21	336	16	267	60	199	245
February	6	355	27	270	60	199	245
	21	13	37	273	60	198	245
March	6	28	46	275	61	198	246
	21	45	56	276	62	197	246
April	6	61	66	278	64	197	245
	21	76	76	278	65	196	245
May	6	87	86	278	67	195	245
	21	94	95	277	69	195	244
June	6	93	106	276	71	195	244
	21	85	115	274	73	194	244
July	6	79	125	272	75	195	243
	21	81	135	270	76	195	243
August	6	90	145	269	78	195	243
	21	102	154	269	79	196	243
September	6	118	164	269	80	197	243
	21	134	174	270	81	198	243
October	6	151	184	271	81	199	244
	21	169	193	273	80	200	244
November	6	188	204	276	80	201	244
	21	206	214	279	79	201	245
December	6	225	224	282	78	202	246
	21	243	234	285	76	203	246
Conjunction:							
Superior		—	Sept. 7	—	May 31	Oct. 11	Nov. 27
Inferior		June 17	—	—	—	—	—
Opposition:		—	—	June 24	Dec. 9	Apr. 6	May 25

Mercury moves so quickly among the stars that it is not possible to indicate its position on the star charts at a convenient interval. The monthly notes must be consulted for the best times at which the planet may be seen.

The positions of the other planets are given in the table on the opposite page. This gives the apparent longitudes on dates which correspond to those of the star charts, and the position of the planet may at once be found near the ecliptic at the given longitude.

Examples:

(1) *What is the bright planet low in the south-east before dawn on March* 20?
Star chart 6L shows the south-eastern sky at this time, and it will be seen that the longitude of the planet is about 280 to 290°. The table opposite shows that the only planet near this position is Jupiter.

(2) *Where may Saturn be found on the night of November* 8?
From the table opposite the longitude of Saturn at this time is seen to be 80°. Chart 10L shows that the planet at this longitude will be well up in the east above Orion at 21^h in early November, and high in the south (charts 12L and 1L) by the early morning hours.

The Planets and the Ecliptic

The paths of the planets about the Sun all lie close to the plane of the ecliptic, which is marked for us in the sky by the apparent path of the Sun among the stars, and is shown on the star charts by a broken line. The Moon and planets will always be found close to this line, never departing from it by more than about 7 degrees. Thus the planets are most favourably placed for observation when the ecliptic is well displayed, and this means that it should be as high in the sky as possible. This avoids the difficulty of finding a clear horizon, and also overcomes the problem of atmospheric absorption, which greatly reduces the light of the stars. Thus a star at an altitude of 10 degrees suffers a loss of 60 per cent of its light, which corresponds to a whole magnitude; at an altitude of only 4 degrees, the loss may amount to two magnitudes.

The position of the ecliptic in the sky is therefore of great importance, and since it is tilted at about 23½ degrees to the equator, it is only at certain times of the day or year that it is displayed to the best advantage. It will be realized that the Sun (and therefore the ecliptic) is at its highest in the sky at noon in midsummer, and at its lowest at noon in midwinter. Allowing for the daily motion of the sky, these times lead to the fact that the ecliptic is highest at midnight in winter, at sunset in the spring, at noon in summer and at sunrise in the autumn. Hence these are the best times to see the planets. Thus, if Venus is an evening star, in the western sky after sunset, it will be seen to best advantage if this occurs in the spring, when the ecliptic is high in the sky and slopes down steeply to the north-west. This means that the planet is not only higher in the sky, but will remain for a much longer period above the horizon. For similar reasons, a morning star will be seen at its best on autumn mornings before sunrise, when the ecliptic is high in the east. The outer planets, which can come to opposition and are then in the south at midnight, are best seen when opposition occurs in the winter months. Clearly the summer is the least favourable time to observe the planets, for the ecliptic is always low in the sky on summer nights.

Notes on the Planets in the monthly diagrams

The following general notes on observing the planets are followed by detailed month-by-month accounts of the behaviour of the planets, and of other interesting phenomena. These monthly notes include diagrams of the apparent movements of the planets at favourable times of the year. Additional notes on other astronomical phenomena will be found on the following pages.

The inferior planets, Mercury and Venus, move in smaller orbits than that of the Earth, and so are always seen near the Sun. They are most obvious at the times of greatest angular distance from the Sun (greatest elongation), which may reach 28 degrees for Mercury, or 47 degrees for Venus. They are then seen as evening stars in the western sky after sunset (at eastern elongations) or as morning stars in the eastern sky before sunrise (at western elongations). The succession of phenomena, conjunctions and elongations, always follows the same order, but the intervals between them are not equal. Thus, if either planet is moving round the far side of its orbit its motion will be to the east, in the same direction in which the Sun appears to be moving. It therefore takes much longer for the planet to overtake the Sun—that is, to come to superior conjunction—than it does when moving round to inferior conjunction, between Sun and Earth. The intervals given in the following table are average values; they remain fairly constant in the case of Venus, which travels in an almost circular orbit. In the case of Mercury, however, conditions vary widely because of the great eccentricity and inclination of the planet's orbit.

		Mercury	*Venus*
Inferior conj.	to Elongation West	22 days	72 days
Elongation West	to Superior conj.	36 days	220 days
Superior conj.	to Elongation East	36 days	220 days
Elongation East	to Inferior conj.	22 days	72 days

The greatest brilliancy of Venus always occurs about a month *before* greatest western elongation (as a morning star), or a month *after* greatest eastern elongation (as an evening star). No such rule can be given for Mercury, because its distance from Sun and Earth can vary over a wide range.

Mercury is not likely to be seen unless a clear horizon is available; it is seldom seen as much as 10 degrees above the horizon in the twilight sky. In general, it may be said that the most favourable times for seeing Mercury as an evening star will be in spring, some days before greatest eastern elongation; in autumn it may be seen as a morning star some days after greatest western elongation.

Venus is the brightest of the planets, and may be seen on occasions in broad daylight. Like Mercury, it is alternately a morning and an evening star, and will be highest in the sky when it is a morning star in autumn, or an evening star in spring. Venus is seen to best advantage when it comes to greatest eastern elongation in June; it is then well north of the Sun in the spring months and is a brilliant object in the sunset sky over a long period.

The superior planets, which travel in orbits larger than that of the Earth, differ from Mercury and Venus in that they can be seen opposite the Sun in the sky. The superior planets are morning stars after conjunction with the Sun, rising earlier each day until they come to opposition. They will then be in the south at midnight, and visible all night. After opposition, they are evening stars, setting earlier each evening until they set in the west with the Sun at the next conjunction. The interval between conjunctions or between oppositions is greatest for Mars (over two years). At the time of opposition, the planet is nearest the Earth, and therefore at its brightest. This change in brightness is most noticeable with Mars, whose distance from the Earth can vary considerably; the other superior planets are at such great distances that there is very little change in brightness from one opposition to another. The effect of altitude is, however, of importance, for at a December opposition the planet will be among the stars of Taurus or Gemini, and can then be at an altitude of more than 60 degrees in southern England. At a summer opposition, when the planet is in Sagittarius, it may only rise to about 15 degrees above the southern horizon, and so make a less impressive appearance.

Mars, whose orbit is appreciably eccentric, comes nearest to the Earth at an opposition at the end of August; it may then be brighter even than Jupiter, but rather low in the sky in Aquarius. These favourable oppositions occur every fifteen or seventeen years (1924, 1941, 1956, 1971), but in this country the planet is probably better seen at an opposition in the autumn or winter, when it is higher in the sky. Oppositions of Mars occur at an average interval of 780 days, and during this time the planet makes a complete circuit of the sky.

Jupiter is always a bright planet, and comes to opposition a month later each year, having moved, roughly speaking, from one Zodiacal constellation to the next.

Saturn moves much more slowly than Jupiter, and may remain in the same constellation for several years. The brightness of Saturn depends on the aspect of its rings, as well as on the distance from Earth and Sun. The rings are now well open, and the planet is growing brighter at each opposition.

Uranus, Neptune and *Pluto* are hardly likely to attract the attention of observers without adequate instruments, but some notes on their present positions in the sky will be found in the March, April and May notes.

Phases of the Moon, 1972

New Moon				*First Quarter*				*Full Moon*				*Last Quarter*			
	d	h	m		d	h	m		d	h	m		d	h	m
								(Dec.	31	20	20)	Jan.	8	13	31
Jan.	16	10	52	Jan.	23	09	29	Jan.	30	10	58	Feb.	7	11	11
Feb.	15	00	29	Feb.	21	17	20	Feb.	29	03	12	Mar.	8	07	05
Mar.	15	11	35	Mar.	22	02	12	Mar.	29	20	05	Apr.	6	23	44
Apr.	13	20	31	Apr.	20	12	45	Apr.	28	12	44	May	6	12	26
May	13	04	08	May	20	01	16	May	28	04	28	June	4	21	22
June	11	11	30	June	18	15	41	June	26	18	46	July	4	03	25
July	10	19	39	July	18	07	46	July	26	07	24	Aug.	2	08	02
Aug.	9	05	26	Aug.	17	01	09	Aug.	24	18	22	Aug.	31	12	48
Sept.	7	17	28	Sept.	15	19	13	Sept.	23	04	07	Sept.	29	19	16
Oct.	7	08	08	Oct.	15	12	55	Oct.	22	13	25	Oct.	29	04	41
Nov.	6	01	21	Nov.	14	05	01	Nov.	20	23	07	Nov.	27	17	45
Dec.	5	20	24	Dec.	13	18	36	Dec.	20	09	45	Dec.	27	10	27

All times are G.M.T.

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MONTHLY NOTES, 1972

January

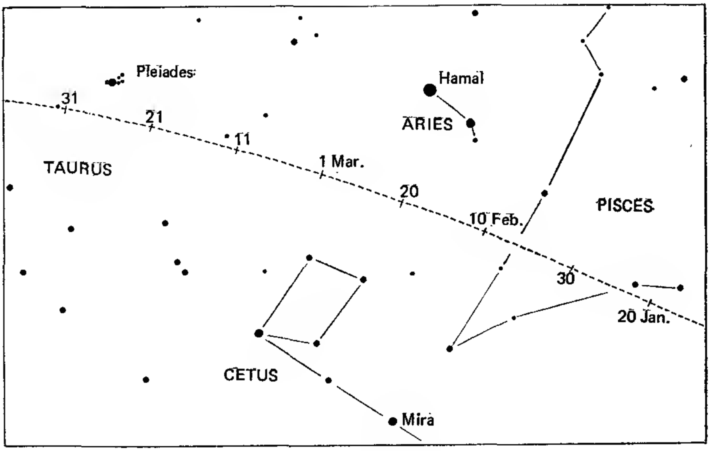
New Moon: 16 January *Full Moon*: 30 January

Earth is at perihelion (nearest to the Sun) on 3 January, at a distance of 91,400,000 miles (147,100,000 km.).

Mercury is at greatest western elongation (23°) on 1 January, and may be visible as a morning star in the first few days of the month, just above the horizon in the south-east before dawn. It should not be confused with the bright planet Jupiter, which is in the same part of the sky. Mercury will be less than a degree north of Jupiter on the morning of 6 January.

Venus is an evening star, setting south of west in mid-evening. It is already very bright (magnitude −3·5) but it is moving north and will become much brighter and higher in the sky, and will be a splendid object in the evening sky in the spring months, and in the morning sky in the autumn.

Mars is also an evening star, and will be seen in the south in the evening twilight, setting about midnight in the west. The planet is fading quite rapidly (magnitude +0·4 to +1.0) as it moves away from the Earth. There is no opposition of Mars in 1972, and throughout the year it moves quite rapidly eastwards round the sky.



Mars, January–March

Jupiter is a morning star, rising in the south-east about an hour before the sun. The planet was in conjunction with the Sun in December last, and is still in Ophiuchus, but it moves into Sagittarius by the end of January, and remains in that constellation during the year. Even in the bright dawn sky, Jupiter is easily recognized, since it is the brightest of all the morning stars this month (magnitude −1·3 to −1·5.

Saturn is an evening star, setting north of west before dawn. The planet was at opposition in November last, and is still well placed for observation in Taurus. It is now retrograding, but reaches a stationary point on 31 January to the west of Aldebaran (see diagram on page 69). Magnitude 0·0 to +0·2.

An annular eclipse of the Sun takes place on 16 January but is visible only in the southern hemisphere (see notes on page 111).

A total eclipse of the Moon on 30 January will be visible in Asia, North and South America and Australasia. The eclipse begins at 9^h 12^m G.M.T. and is total from 10^h 35^m until 11^h 12^m. It ends at 12^h 35^m G.M.T. See notes on page 111.

THE DEPARTURE OF MARS

Mars, having approached the Earth to its closest in August 1971, has now drawn away from us, and is receding all the time. By the end of January is will have faded to the first magnitude (slightly inferior to Aldebaran), whereas in August last year it was the most brilliant object in the entire sky apart from the Sun, the Moon, and Venus.

Because it is a small body, and its distance from us is so variable, Mars undergoes changes in apparent brightness which are more noticeable than with any other planet. Venus and Jupiter are always strikingly brilliant when they are visible at all, and Saturn remains between magnitudes 0 and 1 almost all the time. Mars, however, can be either exceptionally bright or else relatively obscure; at its dimmest it is comparable with Polaris, and unwary observers can all too easily mistake it for an ordinary red star. Throughout 1972 it will be badly placed. It will become steadily less and less evident until it reaches conjunction in September; it will then reappear as a morning object, but even by the end of the year it will still be well below the first magnitude. However, the 1973 opposition will again be close – not quite so near as that of 1971; but, to European observers, there is ample compensation in the fact that Mars will be in Pisces, and hence much higher up in the northern-hemisphere sky.

Of course, adequate telescopes will still show markings on the Martian disk; but modest instruments will not show very much, and for most amateurs Mars may be to all intents and purposes disregarded throughout 1972.

EPSILON AURIGÆ

One of the most interesting stars in the entire sky is well on view this month. It lies near Capella, and marks the apex of a triangle of relatively faint stars which once earned the nickname of the 'Hædi' or Kids. Of the three, the faintest, Zeta Aurigæ, is an eclipsing binary with a period of 972 days; the apex, Epsilon Aurigæ, is also an eclipsing binary – but of most unusual type. The period is 27·1 years, so that minima are infrequent; the primary is an extremely luminous F2-type supergiant, with a mass about 35 times that of the Sun. The secondary cannot be seen directly, though it radiates strongly in the infrared. Its mass has been estimated at 23 times that of the Sun, and its diameter at over 2000 million miles. This would make it the largest single star known, and it could contain all the orbits of the planets round our Sun out to, and somewhat beyond, Uranus.

The eclipses last for 700 days each, but during the central 330 days a constant 48 per cent of the light of the primary is still visible, so that to the naked eye the variations are not striking (Epsilon Aurigæ never fades to much below the fourth magnitude.) During an eclipse, some absorption lines presumably associated with the secondary component are visible; ordinarily, the only lines visible are those due to the primary.

It has been assumed that the system is a very young one, and that the secondary is still shrinking from the stage of formation, in which case it would not yet have reached the Main Sequence. However, a new suggestion, due to A. G. W. Cameron in the United States, puts a very different complexion on matters. Cameron maintains that the system is far advanced in its evolution, and that the primary has moved off the Main Sequence, so that it is now burning helium. The secondary was originally the more massive star of the two, and suffered extensive mass-loss during its Red Giant stage; it has then suffered an 'implosion', and what is left becomes a 'non-luminous singularity', or black hole. Cameron has coined the term 'collapsar' for a body in this state.

If this is so, then the system is very different from anything previously recorded, even though collapsars have long been known to be theoretical possibilities (or even probabilities). We are left with a very small, super-dense object, in an area from which no light can escape. Around it must be scattered material, the débris of the implosion which still remains outside the black hole; this takes the form of a disk of solid particles, orbiting the collapsar itself. In time, many of these particles will spiral inward, and in this case they will be captured by the collapsar – and so far as we are concerned, will disappear.

The theory is highly intriguing, though as yet it must be regarded as unproved, and a certain amount of theoretical speculation is inevitable. But whether Epsilon Aurigæ turns out to be a system including a collapsar, or whether it is merely a vast eclipsing binary, it is still of remarkable importance. Moreover, in our present experience it is unique, even though with the naked eye, or even with a telescope, it looks like a perfectly normal third-magnitude star!

THIS MONTH'S ECLIPSES

Neither of the January eclipses can be seen from Europe or the United States. The solar eclipse is of no special interest; it is annular, and, of course, the glorious phenomena of totality, such as the corona and the prominences, cannot be seen.

February

New Moon: 15 February *Full Moon*: 29 February

Mercury is in superior conjunction on 17 February and will not be visible until the end of the month, when it moves out to eastern elongation as an evening star.

Venus is a brilliant evening star (magnitude −3·5 to −3·7), setting in the west in the late evening in a dark sky.

Mars is an evening star, moving direct from Pisces into Aries in mid-February. As it moves north it has to cover a longer arc in its daily apparent motion across the sky, and as a result it continues to set at the same time (about midnight) every day for some months. The planet continues to grow fainter (magnitude +1·0 to +1·3) with increasing distance from the Earth.

Jupiter is a morning star, rising two to three hours before sunrise in the south-east. It is now in Sagittarius, but is much brighter (magnitude −1·5 to −1·6) than any of the stars of this constellation.

Saturn will be seen in the south at sunset, and sets north of west soon after midnight. The planet is now moving direct in Taurus and forms an interesting group with Aldebaran and the Pleiades. It continues to fade a little as its distance increases (magnitude +0·2 to +0·3).

LEAP YEAR

1972 is exactly divisible by 4; therefore this is Leap Year, and February will have 29 days instead of its customary 28. The adjustment is necessary because the Earth goes round the Sun not in 365 days but in 365¼. Every four years, therefore, the error adds up to a complete day; and if no adjustment were made, Christmas in Europe and the United States would finally work through to the middle of the hot season of the year! To make the adjustment even more exact it is necessary to 'drop' a Leap Year occasionally, and in the Gregorian Calendar, which we use today, a century year is a Leap Year only if it is exactly divisible by 400. Thus 1900 was not a Leap Year, but 2000 will be.

By the time that this system was introduced, in the year 1582, there was already an error of 10 days from the old Julian Calendar, which had been established by Julius Cæsar in 46 B.C. according to the advice of the Alexandrian astronomer Sosigenes. In 1582, by order of Pope Gregory XIII, the ten days were omitted, and 4 October was followed immediately by 15 October. Gradually other countries followed suit; for instance, France, Italy and Spain, where the change was adopted at once (1582), were succeeded by Austria, Czechoslovakia, and others around 1583; Denmark, Holland, and most of Germany between 1610 and 1701; and in Britain in 1752, by which time the error had accumulated to 11 days, and 3 September was followed immediately by 14 September. (Demonstrations against the change ensued, showing that pointless and rowdy demonstrations are by no means confined to the twentieth century!) The last European countries to adopt the Gregorian calendar were Greece in 1924 and Turkey in 1927.

A VERY RED STAR

Below the brilliant Orion lies a much fainter constellation, Lepus (the Hare) – so named becauses the hare was a creature which the mythological Orion was fond of hunting. Lepus is not distinctive, and it has only two stars above the third magnitude. These are Alpha Leporis or Arneb (magnitude 2·6) and Beta or Nihal (2·8). Arneb is actually a very luminous supergiant, lying at a distance of at least 900 light years from us. If it lay at a distance of 10 parsecs or 32·6 light years, it would shine more brilliantly than Venus, and would be visible in broad daylight.

Telescopically, probably the most interesting object in Lepus is the so-called Crimson Star, a nickname given by the last-century astronomer Hind to the variable R Leporis. This February it is not at maximum, but it is visible with any small telescope. At its brightest it can reach magnitude 5·9, so that it is then on the fringe of naked-eye visibility; at minimum it drops to about magnitude 10·5, which is still within the range of a modest instrument. Its period is 430 days; but as it is a long-period of the Mira class, neither the period nor the amplitude is entirely constant.

R Leporis is of spectral type N. It is intensely red; indeed, it is undoubtedly one of the reddest stars in the sky, and this makes it easily identifiable. The surface temperature is less than 3000 degrees Centigrade, as against 6000 degrees for the Sun; but R Leporis is much the more luminous, and is far larger. Its position is R.A. 4^{h} 57^{m}, declination $-14°$ $53'$.

STAR-COLOURS WITH THE NAKED EYE AND BINOCULARS

Any casual glance at the night sky will show that the stars are not all of the same colour. Those of early spectral type are white or bluish-white, while late-type stars are orange or orange-red. However, these differences can be seen with the naked eye only for the brighter stars. There can be no doubt of the orange or reddish hues of Betelgeux, Antares, or Aldebaran – but if you look at, for instance, the third-magnitude star Mu Geminorum, in the Twins, its colour is unlikely to be noticed. Yet Mu Geminorum, like Betelgeux and Antares, is of type M. Were it of the first magnitude instead of the third, its colour would be just as striking.

Sirius is a fine example of a white star (spectral type A), but as seen from Europe it usually twinkles violently, and flashes almost all the colours of the rainbow. This, of course, is purely an effect of the Earth's atmosphere, and is particularly evident with Sirius partly because the star is so brilliant and partly because, as seen from European latitudes, it never rises very far above the horizon. Rigel in Orion, too, is white; Capella, which is almost overhead during February evenings, is of the same spectral type as the Sun (G) and so is yellowish.

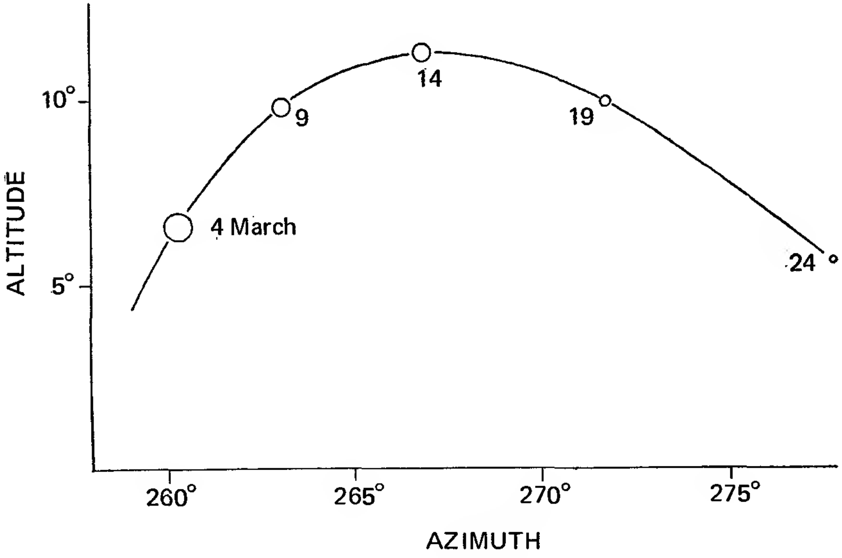
With binoculars, the colours of the stars become much more noticeable, and the hues of many of the fainter stars can also be seen. A good example of this is Kocab or Beta Ursæ Minoris, roughly between the Pole Star and the tail of the Great Bear. It is of the second magnitude, and spectral type K; binoculars bring out its decidedly orange hue. Another reddish second-magnitude star is Alphard or Alpha Hydræ, known as the 'Solitary One' because there are no bright stars anywhere near it. Castor and Pollux, in the Twins, point approximately toward it, and it is easy to locate. It is well seen during evenings in February; Hydra, incidentally, is the largest constellation in the entire sky, but it is also one of the dullest, and Alphard is its only conspicuous star.

March

New Moon: 15 March *Full Moon*: 29 March

Equinox: 20 March

Mercury is at greatest eastern elongation (18°) on 14 March, and is then favourably placed as an evening star in the western sky just after sunset. The diagram shows the changes in altitude and azimuth (true bearing from the north through east, south and west) of Mercury on successive evenings when the Sun is six degrees below the horizon; this will be about thirty-five minutes after sunset at this time of year. The changes in brightness are roughly indicated by the size of the circles, and it will be seen that Mercury is brightest before the date of elongation. The planet is in inferior conjunction on 31 March.



Mercury, March 1972

Venus is a brilliant evening star (magnitude −3·7 to −3·9) and is visible for more than four hours after sunset. The planet is at perihelion on 25 March, and although the orbit is nearly circular, there is a difference of about a million miles between the perihelion and aphelion distances. It is this circumstance, combined with the planet's apparent position north of the Sun, that makes it such a splendid object in the northern hemisphere this year. Conditions can be a little more favourable when eastern elongation occurs in June (see page 51), as in 1967.

Mars is still an evening star setting north of west at midnight, but growing steadily fainter (magnitude +1·4 to +1·6). It moves into Taurus towards the end of the month, and will be seen south of the Pleiades. Its rapid movement will then be obvious as it draws nearer to Saturn.

Jupiter now rises in a dark sky in the south-east in the early hours of the morning, and continues to grow brighter during the month (magnitude −1·6 to −1·8).

Saturn is still an evening star, but sets north of west at midnight at the end of March. It will then be seen between Aldebaran and the Pleiades, but it has now reached its minimum brightness, its magnitude being +0·4.

Pluto is at opposition on 21 March at a distance of about 2820 million miles (4535 million km.). Its position in the constellation Coma Berenices is shown in the diagram on page 98, but it is too faint to be seen with small instruments (magnitude +14).

Occultation of the Pleiades on 19 March is referred to on page 112.

THE ORBITS OF THE PLANETS

Venus, at perihelion this month, moves in an orbit of low eccentricity; indeed its path is more circular than that of any other planet. Yet in general it must be said that the planetary orbits are not really eccentric, and the egg-shaped paths shown in so many diagrams in popular books are considerably exaggerated, for the sake of clarity. The Earth's distance from the Sun ranges between 91½ and 94½ million miles – a range of only 3 million miles, while the mean average distance is 93 million. Drawn to a scale which would fit comfortably on a page in this book, the orbit would look remarkably circular.

The following table gives the maximum and minimum distances from the Sun of the various planets, together with their orbital eccentricities:

	Distance from Sun, in millions of miles		*Orbital eccentricity*
	Maximum	*Minimum*	
Mercury	43	29	0·206
Venus	67·6	66·7	0·007
Earth	94·6	91·4	0·017
Mars	154·5	128·5	0·093
Jupiter	506·8	459·8	0·048
Saturn	937·6	834·6	0·055
Uranus	1867	1699	0·047
Neptune	2817	2769	0·009
Pluto	4566	2766	0·248

Only in the case of Pluto is the eccentricity really appreciable, and the orbit is also more sharply inclined to the ecliptic than those of the other planets (17 degrees), so that it can depart from the Zodiac; at present it is in the constellation of Coma. It next reaches perihelion in 1989; the sidereal period is about 250 years.

It must be remembered that the orbital elements of the planets are not constant, owing to mutual perturbations, and that the figures given in the above table represent the mean values, though the range in eccentricity for any particular planet is not very great.

So far as observational conditions are concerned, the effects of orbital eccentricity are most obvious for Mars. When the planet reaches perihelion and opposition simultaneously, or nearly so – as in 1971 – it can have an apparent diameter of 25 seconds of arc; but if opposition occurs near aphelion, as will occur in 1980, the maximum apparent diameter will be less than 14 seconds of arc.

MERCURY

Mercury is favourably situated for part of this month, and should be easily visible with the naked eye after sunset, always provided that the horizon is free of cloud or mist and that there are no inconvenient artificial lights around. Binoculars are a great help in searching for it, but it is unwise to start sweeping until the Sun has actually set. Otherwise, there is always the danger that the Sun will come into the field of view, with disastrous and permanent injury to the observer's eyesight.

A small telescope will show the phase of Mercury, but surface details are very elusive, and will not be glimpsed without a large instrument. The features on the disk are unquestionably permanent, and have been mapped, but most of the observing work has been carried out in broad daylight, when Mercury is high up. As yet, it must be admitted that the published maps are of dubious accuracy, and the chart drawn by E. M. Antoniadi some forty years ago, from observations with the 33-inch refractor at Meudon Observatory (near Paris) has probably not been substantially improved.

However, new information should certainly come from the Mercury Mariner, which will by-pass Venus and then swing inward toward Mercury. Photographs should be obtained from close range, and these ought to be clear enough to show the nature of the various light markings and darker features. It is very likely that there will be craters, but these may not be nearly so well defined as those of the Moon or Mars, because of the tremendous variations in temperature that occur on Mercury's surface. These conditions may be expected to have resulted in cracking and crumbling of the outer layers.

Mercury goes round the Sun once in 88 days. It used to be thought that the axial rotation period was also 88 days, in which case the rotation would have been 'captured' or synchronous; this was the view held by Antoniadi*. It has been disproved by radar measures, which have shown that the true period is only 58½ days, and that the rotation is 'locked' with respect to the Earth. This discovery has made a great difference to our ideas of conditions on Mercury. There is no area of permanent day, and no zone of everlasting night; the Mercurian calendar will be extremely peculiar by our standards, and certainly there can be no chance of finding life-forms of the kind we know.

Traces of atmosphere have been reported round Mercury from time to time, but the most recent research indicates that the atmosphere is either entirely lacking or else is negligible by any standards. Curiously, Antoniadi recorded frequent local obscurations on the surface, which he believed to be commoner and more obliterating than those in the atmosphere of Mars; but it seems that for once he must have been mistaken.

No doubt automatic probes will land on Mercury in the foreseeable future, but whether a manned landing will be possible is open to grave doubt. All in all, Mercury is as hostile as any planet in the Solar System.

ARGO NAVIS

So far as observers in Europe and the northern part of the United States are concerned, March evenings give the best opportunity of seeing a few stars of the huge constellation of Argo, the Ship – in mythology, the vessel which carried Jason and his companions in the quest of the Golden Fleece. The brightest part of the now-dismembered constellation is far south in the sky; but in the latitudes of London or New York, some of the stars of Puppis (the ship's Poop) may be seen well above the horizon.

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* See Antoniadi's classic book, *The Planet Mercury*, published in France in 1934. Recently translated into English in Nos. 1, 2 and 3 of the new British periodical, *Astronomy and Space* (June, October, December 1971).

April

New Moon: 13 April *Full Moon*: 28 April

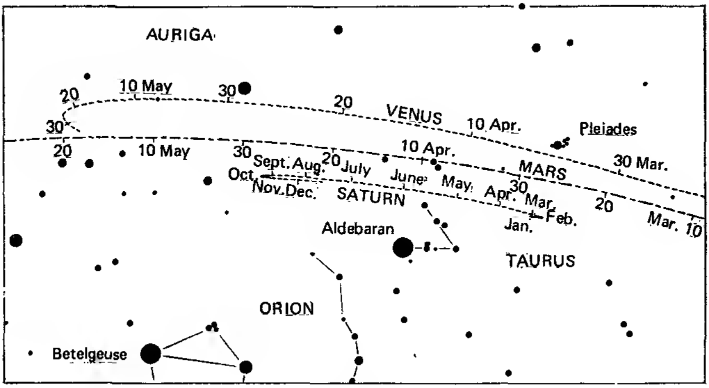
Mercury becomes a morning star in April, but is well south of the Sun and too low in the sky to be seen at dawn. It comes to greatest western elongation (27 degrees) on 28 April.

Venus is at greatest eastern elongation (46 degrees) on 8 April, and in a dark sky it may be seen to be moving eastwards between Aldebaran and the Pleiades. By the end of the month, Venus does not set until nearly midnight. As may be seen from the diagram (on page 69) the planet is in conjunction with Saturn and Mars during the month. On 8 April, Venus passes five degrees north of Saturn, and on 22 April it passes three degrees north of Mars. Venus is far brighter (magnitude −3·9 to −4·2) than either of these planets, but they should not be difficult to find, and form a constantly changing group in an interesting part of the sky.

Mars is an evening star in Taurus, and continues to set about midnight. At the beginning of the month it will be seen between Aldebaran and the Pleiades, passing some degrees north of Aldebaran on 12 April. The star will be seen to be decidedly brighter than the planet (magnitudes: Aldebaran +1·1, Mars +1·7). Mars is in conjunction with Saturn on 1 April (Mars three degrees north of Saturn), and the conjunction with Venus on 22 April is mentioned in the notes above.

Jupiter is a morning star, rising in the south-east at 2^h at the beginning of the month. By the end of April it will rise at midnight, and will be seen in the south at dawn. The planet reaches a stationary point on 25 April, and is steadily growing brighter as it approaches opposition (magnitude −1·8 to −2·0). See diagram on page 77.

Saturn now sets before midnight and will only be seen for a short time in a dark sky, in the west between Aldebaran and the Pleiades.



Saturn, 1972

Uranus is at opposition on 6 April and at this time will be just visible to the naked eye (magnitude +5·7). It will be found in the constellation Virgo (see diagram on page 98) and in a telescope it appears as a greenish disk. The distance of Uranus at opposition is about 1614 million miles (2600 million km).

VENUS AT ITS BRIGHTEST

Venus is now a glorious object, dominating the evening sky. Early in the month it is a half-disk, as any small telescope will show. Under favourable conditions, it may even be seen to cast a distinct shadow.

It is small wonder that the ancients named Venus in honour of the Goddess of Beauty; but we now know that as a world, the planet is neither beautiful nor welcoming! Before the age of space-probes, very little was known about the conditions there, and there was considerable support for a theory due to F. L. Whipple and D. H. Menzel, according to which the surface was covered mainly by water. However, preliminary results from the U.S. vehicle Mariner 2, in late 1962, showed that the surface temperature is much too high for liquid water to exist there, even allowing for the great atmospheric pressure.

More recently, the Russians have sent probes down to the surface, using parachutes to bring them through the dense, all-concealing atmosphere. In 1970, Venera–7 made a successful soft landing, and sent back data for approximately half an hour after arrival, confirming that the temperature is little less than 900° Fahrenheit and that the atmospheric pressure it as least 90 times that of the Earth's air at sea-level. The atmosphere seems to be made up almost entirely of carbon dioxide. Meantime, radar studies carried out by American scientists had shown that the surface is not uniform; there are various patches which may be mountainous areas or plateaux.

In size and mass Venus is almost the twin of the Earth, and the distance from the Sun is only about 26 million miles less on average. Why, then, are the two worlds so different in condition? We have to admit that we do not know. Presumably Venus's greater proximity to the Sun has a great deal to do with it, but the mystery remains unsolved.

There is another mystery, too. All the best evidence indicates that Venus rotates very slowly; the period is given as 243 days, and the spin is retrograde. Yet visual and photographic observations carried out by French astronomers indicate a rotation of only 4 days! It has been suggested that the atmosphere rotates much more quickly than the solid body of the planet, but this does not seem very plausible. In general, it is thought that the visual work must be misleading; but on this point there is a definite divergence of opinion.

With small telescopes it is sometimes possible to see vague, cloudy markings on Venus, together with bright areas near the cusps of the crescent which may or may not indicate the polar zones; but all efforts to work out a reliable rotation period in this way have ended either in complete failure or else in results which are very much open to challenge.

AN ASTRONAUTICAL ANNIVERSARY

Eleven years ago (on 12 April, 1961) the first space-flight was made. Yuri Gagarin, in Vostok I, went round the Earth, reaching a maximum height of 203 miles, and staying aloft for 1 hour 48 minutes. Nowadays we know a great deal about the effects of weightlessness; radiation hazards; problems of communication, and so on. When Gagarin was sent into space, he knew none of these things, so that his journey was a pioneer venture in every sense of the term. It is tragic that he was killed in an ordinary aircraft crash some years later.

Less than a month later, on 5 May, 1961, Alan Shepard became America's first space-man when he went on a brief, sub-orbital 'hop'. In 1971, Shepard made a successful landing on the Moon in Apollo 14. Progress in the intervening years had been quicker than even the wildest optimists had dared to hope.

URSA MAJOR

During April evenings the constellation of Ursa Major is almost overhead as seen from Britain and the northern United States. With its seven leading stars arranged in a characteristic form, it cannot be mistaken. It is known officially as the Great Bear, but in Britain it is nicknamed the Plough, and in America it is called the Big Dipper. It is not far from the north celestial pole, so that from cities such as London or New York it is circumpolar; it can always be seen somewhere whenever the sky is sufficiently clear and dark. From southern countries, such as Australia, it is permanently invisible.

To be accurate, Ursa Major contains many stars as well as those of the Plough; it is a large constellation, and there are many interesting objects in it, including the Owl planetary nebula (unfortunately much too faint to be seen with small telescopes).

The seven Plough stars are Alpha (Dubhe), Beta (Merak), Gamma (Phad or Phekda), Delta (Megrez), Epsilon (Alioth), Zeta (Mizar) and Eta (Alkaid or Benetnasch). Of these, five make up a moving cluster whose members share a common motion through space. The two unconnected stars are Alkaid and Dubhe, which are rather further away (210 and 107 light-years respectively). Over a sufficiently long period of time the Plough will lose its shape, since Alkaid and Dubhe are moving across the sky in a direction opposite to that of the remaining five. All the Plough stars are white with the exception of Dubhe, which is of spectral type K, and is distinctly orange when viewed through binoculars or a telescope.

Mizar is the most famous double star in the sky. It forms a naked-eye pair with Alcor, and in a small telescope Mizar itself is seen to be made up of two rather unequal components. It is a binary, but the period of revolution is extremely long. Megrez is now a magnitude fainter than any of the other Plough stars, and may have faded during the past 1000 years or so, though the evidence is somewhat slender. It has been suspected of slight variability in modern times.

Ursa Major contains no star of the first magnitude; the brightest are Alioth and Dubhe (1·8) and Alkaid (1·9), but it is as easily recognized as any constellation in the sky, and there can be relatively few people who do not know it.

May

New Moon: 13 May *Full Moon* 28 May

Mercury is moving towards superior conjunction, and will not be visible during the month.

Venus now begins to draw in towards inferior conjunction, and by the end of the month it sets at about 22^h. The planet is moving more slowly as it approaches a stationary point on 26 May, and as a result Mars will overtake Venus on 17 May (Venus three degrees north of Mars. See diagram on page 69).

Mars moves into Gemini in mid-May, and now begins to set a little earlier each evening. The conjunction of Venus and Mars is mentioned above, and the two planets will remain within a few degrees of each other for some time. There is, of course, a marked contrast in brightness, Venus being about six magnitudes brighter than Mars – about 250 times as bright. (Magnitudes: Venus −4·1, Mars +1·8.)

Jupiter rises at midnight at the beginning of May, and grows still brighter as it approaches opposition (magnitude −2·0 to −2·2). The planet is moving retrograde in Sagittarius, so that it is very low in the sky, which is never really dark at this time of the year. But even under these conditions, the brilliance of Jupiter is quite unmistakable, and there is no other bright planet nearby.

Saturn sets shortly after the Sun, and reaches conjunction on 31 May.

Neptune is at opposition on 25 May. Its path during the year is shown in the diagram on page 77, but it is not visible to the naked eye (magnitude +7·7). In a small telescope it appears as a bluish disk. The distance of Neptune at opposition is about 2720 million miles (4380 million km.).

An occultation of Antares occurs in the early morning of 1 May (see page 112).

An occultation of Mars by the crescent Moon will be visible in the evening of 15 May (see page 112).

A PLANETARY CONJUNCTION

For part of this month Venus and Mars will be close together in the sky, but there is, of course, no occultation of one planet by the other. Mutual occultations are in fact very rare, and only a few have been observed. The first on record seems to have been that of 3 October, 1590, when an occultation of Mars by Venus is said to have been watched by Michael Möstlin, Professor of Mathematics at Heidelberg; and on 17 May, 1737, J. Bevis, at Greenwich, had a view of an occultation of Mercury by Venus. On 21 July, 1859, Venus and Jupiter were so close together that they could not be separated without optical aid, though there was no actual occultation..

It has often been suggested that the Biblical Star of Bethlehem was due to a very close conjunction of two bright planets; but this theory, attractive though it may sound, has been completely discredited. Whatever the Star of Bethlehem may have been, it was not a planetary conjunction.

THE SIZE OF NEPTUNE

Neptune, at opposition this month, is a giant planet, and is generally regarded as the 'twin' of Uranus. (The two are not close neighbours; Neptune is further from Uranus than we ourselves are from Saturn. It is not always easy to appreciate that the more distant planets are very 'spread-out'.) The diameter of Uranus is 29,300 miles. That of Neptune is less easy to measure; observations made in 1949 by G. P. Kuiper and in 1953 by H. Camichel have a value of less than 28,000 miles, in which case Neptune would have a density over twice that of water. There has never been any doubt that Neptune is more massive than Uranus.

The apparent diameter is only a little over 2 seconds of arc, so that observations of this kind are far from easy. Fortunately, another method is available. At intervals Neptune may occult a star, and the duration of the occultation will, of course, yield a value for the planet's diameter. Such an occultation took place on 7 April, 1968, and a full programme of observations was organized by Gordon E. Taylor at the Royal Greenwich Observatory, Herstmonceux. Results came in from sites as far afield as Japan, New Zealand and Australia. When the results were analysed, Taylor was able to give a value for the diameter of 31,500 miles (equatorial) and 31,100 miles (polar). This means that Neptune is, after all, somewhat larger than Uranus, and its density is only 1·8 times that of water, practically the same as that of Uranus.

Binoculars will show Neptune easily, but it looks very like a star. Even powerful telescopes will show almost nothing on its rather bluish disk. However, it should be by-passed by an automatic probe during the 1980s, and if all goes well close-range views of it will be received. Of its two satellites, Triton is brighter than any of the attendants of Uranus, and is not a difficult object; the other, Nereid, is excessively faint, and has a highly eccentric orbit.

WILLEM DE SITTER

One hundred years ago, on 6 May, 1872, Willem de Sitter was born at Sneek, in Friesland. He became one of Holland's most famous astronomers, and will always be associated with his outstanding contributions to the theory of relativity.

De Sitter graduated at Groningen University, and for a time worked at the Cape Observatory in South Africa. He then returned to his native country, and in 1918 became Director of the Observatory at Leyden. In his later years he was occupied principally with theoretical researches into the nature and origin of the universe; the ‘de Sitter universe’, finite yet unbounded, was calculated to be 2000 million light-years in radius and to contain 80,000 million galaxies. It is now known that the universe is much larger than de Sitter had believed, but his researches were of fundamental importance. He died at Leyden on 19 November, 1934.

FAINT, REMOTE GALAXIES

The distances of galaxies are measured principally by the red shifts in their spectra, which are assumed to be Doppler shifts. Many galaxies lie well beyond the 2000 million light-years which de Sitter had regarded as the total extent of the universe; radio methods have shown that some systems are at least four times as remote as this.

Individual stars cannot be seen in very distant galaxies, and it is only our nearer neighbours, such as the Andromeda Spiral (at a mere 2·2 million light-years!) which appear so spectacular in photographs. Faint galaxies are remarkably numerous, and in some regions of the sky actually outnumber stars seen in our own Galaxy.

Because of the absorbing effects of material lying near the main plane of our Galaxy, outer systems cannot be seen close to the Milky Way; they are hidden, and there is a distinct ‘zone of avoidance’. Away from the Milky Way, there is much less absorption. The area of the ‘bowl’ of Virgo, for instance, is extremely rich in galaxies, as photographs show.

The ‘bowl’ is easily found. Follow round the tail of the Great Bear and locate Arcturus; if the line is continued and curved, it will reach Spica in Virgo, which is of the first magnitude. Virgo itself is made up of a kind of distorted ‘Y’ of stars, of which the ‘base’, Gamma Virginis, is a splendid binary. The ‘bowl’ is marked by this Y-form, and is bounded by Denebola or Beta Leonis in the adjacent constellation of the Lion. Unfortunately, small telescopes are not adequate to show the many galaxies in this part of the sky.

June

New Moon: 11 June *Full Moon*: 26 June

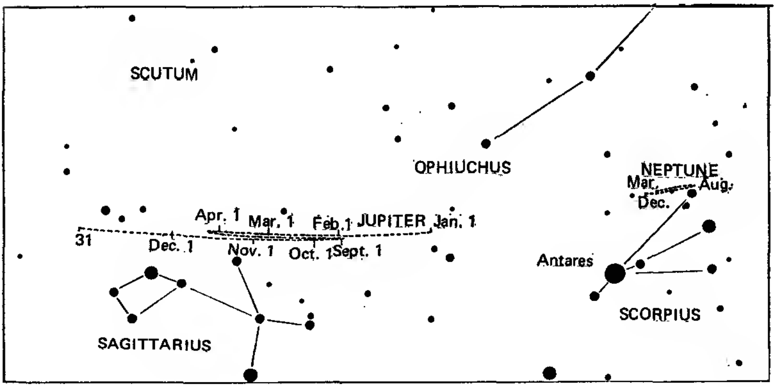
Solstice: 21 June

Mercury is in superior conjunction on 4 June, and will not be seen during the month.

Venus sets north of west about two hours after sunset at the beginning of June, but it moves rapidly in towards inferior conjunction on 17 June, so that it will only be visible in the evening twilight for the first few days of the month.

Mars is now only a second-magnitude object, setting in mid-evening to the north of west. It moves into Cancer at the end of the month, and may then be seen south (i.e. to the left) of Castor and Pollux as they set in the western sky.

Jupiter is at opposition on 24 June when it will be at a distance of 392,300,000 miles (639,000,000 km.) from the Earth. This is



Jupiter and Neptune

somewhat nearer than it was in 1971, and it is a little brighter (magnitude −2·2). Although the sky is never really dark in the summer months, the four big moons of Jupiter may readily be observed with a small telescope, all four of them at this season undergoing eclipse during each revolution.

Saturn now becomes a morning star in Taurus, and by the end of the month rises about an hour and a half before sunrise. It will be found to the east of Aldebaran, and is nearly a whole magnitude brighter than that star (magnitudes: Saturn +0·3, Aldebaran +1·1).

JUPITER AT ITS SOUTHERNMOST

Though Jupiter is at opposition this month, it is not well placed for observers in northern latitudes, because it will be rather low in the sky. In general, Jupiter moves along the Zodiac by one constellation per year; thus it has now entered a period of southern declination, and will not return to the northern hemisphere until 1976.

However, any small telescope will show features of interest – the four Galilean satellites are easy objects, and there are even reports of their having been seen with the naked eye, though this is possible only when Jupiter is high up. (Many authorities are sceptical about the observations, but a few reports do seem to rest upon sound evidence.)

Jupiter is a rewarding object for study with an adequate telescope, because its surface is always changing, and determinations of the latitudes and longitudes of the various features are of great value. It is probably true to say that much of our knowledge of the way in which Jupiter has behaved over the past seventy or eighty years is due to amateur work. In this programme the Jupiter Section of the British Astronomical Association has played a leading rôle. Past directors of this section include T. E. R. Phillips; B. M. Peek, author of the standard book on the subject; and A. F. O'D. Alexander, whose death in 1971 is so deeply regretted.

R CORONÆ

One of the most interesting variables in the sky is now well on view. R Coronæ, in the 'bowl' of the Northern Crown, has been studied for many years, its variability was discovered by Pigott as long ago as 1795. Generally it is of around magnitude 6, so that it is on the fringe of naked-eye visibility and is prominent with binoculars. Also in the 'bowl', on the opposite side, is a star of magnitude 6·6, which makes a good comparison when R is at maximum.

At irregular intervals, R Coronæ fades abruptly. At a deep minimum it may fall to magnitude 14 or fainter; at other times it may sink only to around magnitude 12; and there are also much shallower minima, as during the summer of 1969, when the star never descended below magnitude 7·5 before returning to maximum. Minima cannot be predicted, there seems to be no semblance of regularity. For long periods there is little variation. This happened between 1925 and 1934, when there were no minima at all.

R Coronæ is the prototype of a small class, the other members of which are decidedly fainter. Moreover, most of the rest lie in the southern part of the sky, so that they are difficult or inaccessible to observers in Europe and the northern United States. The exception is SU Tauri, which is usually of magnitude 9½, but which can fall to 16. Of the southern R Coronæ stars, S Apodis has a maximum magnitude of 9·6; UW Centauri, 9·6; Y Muscæ, 10·5; RY Sagittarii, 6·0; and RS Telescopii 9·3. The rest are fainter. SU Tauri fell to minimum in early 1971.

R Coronæ and other stars of its kind are hydrogen-poor and carbon-rich. Their variation seems to be of a different type from that of the pulsating stars, and the spectral types show a wide range; thus R Coronæ itself and SU Tauri are both of type G or thereabouts, whereas the southern variables RT Normæ, RZ Normæ, and RS Telescopii are of type R! It has been suggested that R Coronæ stars are not intrinsically variable at all, but are immersed in nebulosity, so that their apparent brightness depends upon the amount of the intervening material. This theory sounds plausible at first glance, but there are so many objections to it that it has now been generally abandoned.

Carbon particles may well be the basic cause of the changes in magnitude. It may be that clouds of small carbon particles are formed in the star's outer layers, thereby acting as a screen, or it may be that matter is ejected as a shell around the star, and that this shell contracts, so that the density is increased and carbon particles are deposited.

During a minimum, complicated changes occur in the spectrum of R Coronæ. Emission lines appear, though they weaken again once the star has fallen to below about magnitude 10; and it seems that these may be due to matter ejected from the surface of the star through the gaseous envelope surrounding it.

Our knowledge of the evolutionary position of these strange stars is still very fragmentary. On the H–R Diagram they are far to the right of the Main Sequence, in the supergiant region; they are of Population II, so that they are well advanced in their careers. W. P. Bidelman has suggested that there may be a link between R Coronæ stars and planetary nebulæ, since there are undeniable similarities in spatial distribution, but it is significant that planetary nebulæ are not hydrogen-poor, whereas the R Coronæ variables are.

Amateur astronomers with powerful telescopes can undertake most valuable work in connection with these curious stars, though unfortunately most of the research has to be carried out from sites further south than London or New York. Meantime, both R Coronæ and SU Tauri can be watched. Binoculars are adequate for R Coronæ for most of the time; if you look for it and find that it is absent, then you will know that it is experiencing one of its minima, and you will need a telescope together with a set of specialist charts. Members of the British Astronomical Association can obtain all information, together with charts, from the Director of the Variable Star Section (American observers from the A.A.V.S.O.)

ANTARES

June evenings provide the best possible time for looking at Antares, the brilliant red supergiant in the Scorpion. It is easily identifiable, partly because of its colour and partly because it is flanked to either side by a fainter star – a characteristic shared, among first-magnitude stars, only by Altair in Aquila.

Telescopically, Antares is seen to have a companion of magnitude 7; the distance is 3 seconds of arc, and the position angle is 275°. The companion appears green, partly because of contrast with the red primary. The pair is regarded as fixed, and there has been no certain evidence of change in distance or position angle.

July

New Moon: 10 July *Full Moon*: 26 July

Earth is at aphelion (farthest from the Sun) on 5 July, when its distance will be 94,500,000 miles (152,100,000 km.).

Mercury is at greatest eastern elongation (26°) on 10 July, but it is not very bright, and will be only a few degrees above the horizon in the north-west in the bright evening twilight.

Venus draws out repaidly from the Sun as a brilliant morning star, and by the end of July it rises three hours before sunrise. The planet is at a stationary point again on 9 July, and then begins its rapid direct motion to the east, overtaking Mars again before the end of the year. Venus is at greatest brilliancy (magnitude $-4{\cdot}2$) on 24 July.

Mars now sets an hour or less after the Sun, and since it is only of the second magnitude, it is unlikely to be visible in the bright western sky.

Jupiter is an evening star moving retrograde in Sagittarius, and will be seen in the south in the late evening, a brilliant object of magnitude $-2{\cdot}2$. At the end of the month it sets about three hours before sunrise.

Saturn is a morning star in Taurus, rising in the north-east about an hour later than Venus. The magnitude of the planet remains for some weeks at $+0{\cdot}3$, comparable with the bright stars of Orion which are rising below the planet in the east.

A total eclipse of the Sun on 10 July will be visible along a track extending through eastern Siberia, North America, Nova Scotia to the central Atlantic. A partial eclipse will be seen in

North and South America and from North and West Europe (see notes on page 111). In the British Isles about half of the Sun will be eclipsed at sunset.

A partial eclipse of the Moon on 26 July will be visible in Australasia and in North and South America (see notes on page 111). The eclipse begins at 5^h 55^m and ends at 8^h 36^m G.M.T., rather more than half of the Moon being eclipsed at maximum phase.

This Month's Eclipse of the Sun

Because the track of totality passes through North America, this eclipse should be well observed. The corona may be expected to be of the 'spot-minimum' variety, since the Sun is (or should be!) almost at its least active; it is possible that there will be no sunspots visible, though, of course, no definite predictions can be made, and in any case the present solar cycle, succeeding the very low maximum, is not following a conventional course. If there are any sunspots, it is interesting to compare them with the blackness of the Moon. It is easy to see that there is a great difference, because a sunspot is not really dark; it has a surface temperature of 4000° Centigrade, and its apparent blackness is due to contrast against the still hotter photosphere around. If a sunspot could be seen shining on its own, its surface brilliancy would be greater than that of an arc-lamp.

In Britain the eclipse will be partial only, but will be worth watching. The only safe method, telescopically, is by projection. Neither is it safe to stare straight at the Sun with the naked eye; during other partial eclipses, hospitals have had to treat many cases of 'spots before the eyes' due to injudicious staring.

Frederik Kaiser and the Names of Martian Features

28 July is the centenary of the death of a famous Dutch astronomer, Frederik Kaiser. He was born in Amsterdam in 1808, and became a professional astronomer. When he was appointed Director of the Leyden Observatory, he made careful

studies of double stars, but his principal work was in connection with the planet Mars. He determined the rotation period with great accuracy, and drew up maps of the surface which were the best of their time. Under his supervision the Observatory was modernized and rebuilt, and he continued as Director until his death on 28 July, 1872.

Before 1877, the year in which G. V. Schiaparelli made the famous observations which sparked off the 'canal controversy' which has now ended, the most prominent dark marking on Mars was known as the Kaiser Sea, though it was also known unofficially as the Hourglass Sea. Nowadays, we call it the Syrtis Major, and it is familiar to anyone who has the slightest acquaintance with Martian topography.

The original names for Martian features were introduced by R. A. Proctor, who drew upon all the best available observations, including Kaiser's map of 1864. Proctor's nomenclature was published in 1867, and was adopted by other observers, including N. E. Green, who produced an excellent map on his own account. The basic scheme was to honour astronomers of the past and present, as has been the custom on the Moon. It may be of interest to give a list of Green's names, together with their modern equivalents: the features named by Green as Pratt Bay and Schmidt Bay have been omitted, because their identification is uncertain.

Green's name	*Modern name*
Airy Sea	Mare Boreum
Beer Continent	Aeria, Arabia and Moab
Burckhardt Land	Hesperia
Burton Bay	Margaritifer Sinus
Cassini Land	Ausonia
Christie Bay	Auroræ Sinus
Dawes' Forked Bay	Sinus Meridiani
Delambre Sea	Umbra
De la Rue Ocean	Mare Erythræum
Flammarion Sea	Mare Tyrrhenum

Fontana Land	Dioscuria, Cydonia
Herschel I Continent	Elysium, Aethiopis, Aeolis
Herschel II Strait	Sinus Sabæus
Huggins Bay	Sinus Gomen
Jacob Land	Argyre
Kaiser Sea	Syrtis Major
Lockyer Land	Hellas
Mädler Continent	Chryse and Xanthe
Main Sea	Mœris Lacus
Maraldi Sea	Mare Cimmerium
Oudemans Sea	Utopia
Phillips Island	Deucalionis Regio
Rosse Land	Tempe and Arcadia
Secchi Continent	Memnonia
Terby Sea	Solis Lacus
Webb Land	Eridania

This attractive nomenclature did not survive for long. In 1877, Schiaparelli produced a more elaborate map, and provided new names, which are essentially those in use today even though his list has been modified to some extent.

By that time it was already clear that whatever the dark areas might be, they could hardly be seas. The first challenge to the 'water theory' had been made as long ago as 1863 by Schiaparelli himself, who noted that the dark regions did not reflect the Sun's image as sheets of water ought to do. Liais, a French astronomer who spent much of his active observing life in Brazil, proposed that the dark areas were likely to be vegetation. This theory persisted until very recent times, and is still not completely disproved. However, it seems definite that not all the dark areas are depressed areas, so that the idea of their being old sea-beds must be given up; the Syrtis Major, formerly the Kaiser Sea, is an elevated region.

HERCULES

During July evenings, much of the sky is occupied by large, rather faint constellations such as Hercules, Ophiuchus, and Serpens. Hercules lies in the northern hemisphere, and hardly lives up to his mythological reputation, since his brightest stars (Beta and Zeta Herculis) are only of the third magnitude. The shape of the constellation can be made out without difficulty, but it is by no means prominent, and moonlight will drown it. To the north, Hercules adjoins Lyra and Draco; to the south, it borders Ophiuchus and Serpens.

Undoubtedly the most famous object in Hercules is the globular cluster M.13, which lies between Eta and Zeta (rather nearer to the former star) and is just visible with the naked eye on a clear night if one knows exactly where to look for it. In a moderate telescope it is a fine sight, and it is the most magnificent globular in the sky apart from Omega Centauri and 47 Tucanæ, which are too far south to be visible from Europe. Also in Hercules is another globular, M.92, which forms a triangle with the stars Eta and Pi. M.92 was discovered by J. E. Bode in 1777, and is both bright and condensed. with an integrated magnitude of 6·1. Its distance from us is 37,000 light-years, and its diameter is 88 light-years, so that it is slightly smaller than M.13 as well as being further away.

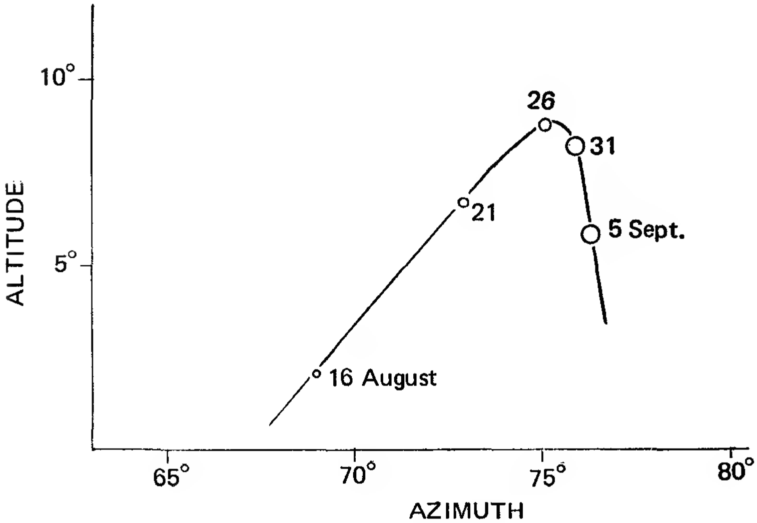
Zeta Herculis is a splendid example of a binary star. It is only 30 light-years away, and so it is separable with modest telescopes even though the period of revolution is only 34 years. At present the distance between the two components is increasing, and will continue to do so until 1988, when the maximum separation will be 1″·6. The magnitudes are 3 and 6½; the primary is a yellow G-type star, considerably more luminous than our Sun.

Alpha Herculis (Rasalgethi) is another double star, the primary is a red supergiant, irregularly variable between magnitudes 3 and 4, while the sixth-magnitude companion appears green, partly because of contrast. Alpha Herculis is rather 'on its own' so far as the rest of the constellation is concerned, and lies near the second-magnitude star Rasalhague, or Alpha Ophiuchi.

August

New Moon: 9 August *Full Moon*: 24 August

Mercury comes to inferior conjunction on 7 August, and then moves rapidly out to greatest western elongation (18°) on 25 August when it will be favourably placed as a morning star, visible to the north of east just before sunrise. The diagram shows the changes in altitude and azimuth of Mercury on successive mornings when the Sun is six degrees below the horizon; this is about thirty-five minutes before sunrise at this season. The changes in brightness are roughly indicated by the size of the circles, Mercury being much brighter after the date of western elongation.



Mercury, August 1972

Venus is a morning star, rising about an hour after midnight in a dark sky. It reaches greatest western elongation (46°) on 27 August, and is a brilliant object in the eastern sky (magnitude −4·2 to −3·9).

Mars is not visible during the month, as it is now close to conjunction with the Sun.

Jupiter is an evening star (magnitude −2·1 to −2·0) setting at midnight in the south-west. It reaches a stationary point on 25 August on the western border of Sagittarius, and afterwards moves direct again.

Saturn rises at midnight at the beginning of the month and in the early morning it will be seen above the sloping figure of Orion in the eastern sky. The planet is still only moderately bright (magnitude +0·3).

The Angular Distances between Bright Stars

August is traditionally the month for meteors, since the Perseid shower is at its maximum during the first fortnight. This year the Moon will not be in evidence when the Perseids are on view, and no doubt the display will be quite spectacular. Despite modern radar methods, visual observations are still of considerable value; and it often happens that the observer wants to estimate the length of the meteor's path. This is best done, of course, by reference to stars near the beginning and end of the trail.

Many observers know at once that it is 5 degrees from Alpha to Beta Ursæ Majoris (the pointers to the Pole Star), and 15 degrees from Alpheratz to Beta Andromedæ, but it is not easy (or necessary!) to memorize long lists. The following table gives the angular distances between selected brilliant stars, and may be of help both to meteor observers and in the general estimation of angular distances in the night sky.

	Distance, degrees
Castor to Pollux	4·5
Betelgeux to Rigel	18·6
Betelgeux to Aldebaran	21·4
Pollux to Procyon	22·8
Rigel to Sirius	23·7
Betelgeux to Procyon	26·0
Rigel to Aldebaran	26·5
Betelgeux to Sirius	27·1
Capella to Castor	30·0
Capella to Aldebaran	30.7
Arcturus to Spica	32·8
Betelgeux to Castor	33·7
Altair to Vega	34·2
Regulus to Pollux	37·0
Regulus to Procyon	37·4
Altair to Deneb	38·0
Rigel to Procyon	38·5
Betelgeux to Capella	39·5
Polaris to Capella	43·4
Pollux to Aldebaran	45·0
Antares to Spica	45·9
Aldebaran to Sirius	46·0
Sirius to Pollux	47·0
Procyon to Capella	51·1
Polaris to Vega	51·6
Regulus to Spica	54·1
Rigel to Capella	54·2
Arcturus to Antares	56.0
Polaris to Castor	57·9
Arcturus to Vega	59·1
Altair to Fomalhaut	59·2
Altair to Antares	60·3
Betelgeux to Regulus	62·4
Capella to Sirius	65·8
Capella to Regulus	69·6
Polaris to Arcturus	71·5
Vega to Antares	71·7
Polaris to Aldebaran	72·9
Rigel to Regulus	75·8
Capella to Deneb	78·2
Polaris to Regulus	78·3
Regulus to Aldebaran	80·1
Arcturus to Deneb	80·8
Deneb to Fomalhaut	81·0
Arcturus to Altair	81·2
Polaris to Altair	81·3
Antares to Fomalhaut	82·9
Arcturus to Pollux	87·4
Vega to Spica	87·8
Rigel to Fomalhaut	89·6
Antares to Deneb	91·7

And for some of the brilliant stars of the far south:

	Distance, degrees
Agena to Alpha Centauri	4·5
Acrux to Agena	11·8
Acrux to Alpha Centauri	15·7
Sirius to Canopus	36·3
Canopus to Achernar	39·4
Canopus to Rigel	46·7
Acrux to Alpha Centauri	15·7
Spica to Alpha Centauri	51·6
Acrux to Antares	53·5
Canopus to Alpha Centauri	58·0
Acrux to Achernar	58·9
Canopus to Betelgeux	60·4
Sirius to Achernar	68·9
Canopus to Fomalhaut	78·5
Arcturus to Alpha Centauri	80·2
Canopus to Castor	86·0
Sirius to Alpha Centauri	88·5
Canopus to Spica	90·2
Altair to Alpha Centauri	91·8

The angular distance between the two brilliant northern stars Capella and Vega is 93·3 degrees; they are on opposite sides of the pole, and so when Capella is near the zenith Vega grazes the horizon as seen from the latitude of Greenwich. In August, after sunset, Vega is almost overhead; Capella will be so low down that any horizon mist will obscure it.

The distance between Rigel in Orion, and Antares in the Scorpion is 144 degrees. The two can never be above the horizon at the same time, and there is an old legend attached to this fact. It is said that Orion, the hunter, boasted that he could kill any living creature; but he had forgotten the scorpion, which crawled out of the ground, stung him in the foot and caused his death. Subsequently Orion was placed in the sky – and the Scorpion was installed in the opposite hemisphere, so that it could never see Orion and could do him no further harm!

TWO FAMOUS FRENCH ASTRONOMERS

Charles Eugene Delaunay was born at Lusigny, in France, in 1816. He was educated in Paris, and became interested in positional astronomy. He was particularly concerned with the motions of the Moon, in which he became the leading authority of his time.

In 1870 there was a crisis at the famous Paris Observatory. The Director was Urbain le Verrier, one of the greatest scientists of the nineteenth century, and who had been responsible for making the calculations which had led to the first identification of the planet Neptune. Unfortunately, Le Verrier was not an easy man with whom to work. His rudeness and short temper were notorious, and finally matters came to a head. He was relieved of the Directorship, and Charles Delaunay was appointed in his place.

Delaunay was much more amenable and popular than Le Verrier had been, but he was given little opportunity to leave his mark at the Observatory. On 5 August, 1872, a hundred years ago, he was boating off Cherbourg when the boat capsized and Delaunay was drowned. Perhaps with some misgivings, the authorities reappointed Le Verrier, who remained as Director until his own death five years later.

Another French centenary this year is that of Ferdinand Jules Quénisset, who was born in Paris on 8 August, 1872. He joined the staff at the Juvisy Observatory in 1906, and discovered two comets as well as taking some excellent planetary photographs.

September

New Moon: 7 September *Full Moon*: 23 September

Equinox: 22 September

Mercury is in superior conjunction on 19 September and will not be visible during the month.

Venus is still a brilliant morning star (magnitude −3·9 to −3·7) but now begins to rise a little later each morning to the north of east. At the beginning of the month it may be seen to rise in a dark sky some degrees below the Twins, Castor and Pollux.

Mars is in conjunction with the Sun on 7 September, and after this date it becomes a morning star in Leo, but is still too close to the Sun to be seen.

Jupiter now sets in the late evening in the south-west. It is moving direct in Sagittarius, and growing fainter as its distance from the Earth increases (magnitude −2·0 to −1·8).

Saturn rises about the same time that Jupiter sets (22^h) and will be in the south at sunrise. It is approaching a stationary point and will be seen above the figure of Orion. The planet is growing a little brighter (magnitude +0·3 to +0·2).

BETA CETI AND SUSPECTED VARIABLE STARS

Well below the Square of Pegasus (as seen from the northern hemisphere) lie two bright stars: Fomalhaut or Alpha Piscis Austrini and Diphda or Beta Ceti. In the Square, Beta and Alpha Pegasi point toward Fomalhaut, while Alpheratz and Gamma Pegasi point approximately toward Beta Ceti. There can be no confusion, because Fomalhaut is a magnitude brighter than Beta

Ceti and is further away from the Square. However, both stars lie in barren regions of the sky, and for this reason they stand out prominently, though from the latitude of Greenwich Fomalhaut at least is always very low over the horizon.

Beta Ceti is of magnitude 2·02, and spectral type K; it is much more luminous than the Sun (its absolute magnitude is 0·8) and its distance is 57 light-years. It is interesting because it has been suspected of variability, and there have been suggestions that it increases, temporarily and irregularly, almost to the first magnitude.

It must be admitted that the evidence for variation in Beta Ceti is extremely slender, and most observers discount it. However, there are many other suspected variables, and naked-eye observers, or those equipped with binoculars, can undertake some interesting work in this field.

In 1890 there appeared the fourth edition of a famous astronomical textbook by G. F. Chambers. In it he gave a list of suspected variable stars; and in his list of confirmed variables he included Beta Corvi, which was said to range between magnitude 2¾ and 3¾. This has certainly not been confirmed. The magnitude is 2·7, and since the spectrum is of type G no variation is really to be expected. The original claim was made by Admiral Smyth, but it seems that it must have been erroneous.

The following stars are given as suspected variables in Chambers' old catalogue:

	Range		*Authority for*
	max.	min.	*variation*
Gamma Pegasi	2½	3	Schwabe. Period 27½ days
61 Ceti	6	7	Sir W. Herschel
Nu Fornacis	5	6	Gould
Gamma Eridani	2½	3½	Secchi
R Eridani	5½	6	Gould
31 Orionis	4¾	6	Gould
Sigma Canis Majoris	4½	5	Gould
Beta Volantis	4	5	Gould

	Range		*Authority for*
	max.	min.	*variation*
Eta Crateris	4½	6½	Houzeau
Epsilon Corvi	3	4	Gould
Delta Ursae Majoris	2½	4	Pigott
Gamma Corvi	2½	3	Gould
Eta Virginis	3	4	Gould
Delta Corvi	2¾	3½	Gould
Eta Ursae Majoris	2	?	Espin and others
Upsilon Boötis	4	4½	Schmidt
Beta Ursae Minoris	2¼	2¾	J. Herschel, Espin. 10½ days?
Mu Draconis	4	5	Sir J. Johnson
Gamma Sagittarii	3	3½	Gould
Beta Cygni	3	4	Klein. Period of years?
Mu Aquilæ	4	5	Gould
Epsilon Draconis	3¾	4¾	Gould. B also variable?
Rho Pavonis	4½	5¼	Gould
Beta Cephei	3	3½	various
Epsilon Pegasi	2	2½	Schwabe. Period 25¾ days?
Eta Pegasi	3	3¼	Christie
Iota Andromedæ	4½	5	Gore

The list is of historical interest. Most of the stars in it are almost certainly non-variable; Beta Cephei is, of course, a very small-amplitude Cepheid, but the variations are too slight to be noticed with the naked eye. However, the amateur who is learning his way around the sky may care to identify the stars in Chambers' list; and when he has gained experience, it may be a pleasant pastime to make a few estimates – just in case any of the stars may prove to be variable after all!

The most celebrated case of a suspected variable is Shedir or Alpha Cassiopeia, in the W. It has long been regarded as a variable with a range of from magnitude 2 to 2¾, but doubts have been cast upon the reality of the changes, and in the catalogue by Kukarkin it is listed as constant. The spectrum is of type K. The star has been under close study recently by the Binocular Group of the Variable Star Section of the British Astronomical Association, directed by John W. MacVey, and the results seem to show that there is a slight variation around a mean magnitude of 2·3. However, further observations are needed. Its neighbour Gamma is, of course, the well-known irregular variable, with a range of from 1·6 to 3·3. Useful comparison stars for both Alpha and Gamma are the remaining stars of the W: Beta (2·3), Delta (2·7) and Epsilon (3·4). Cassiopeia is high in the sky during September evenings, and is so near the Pole that from the latitude of Greenwich it never sets.

TRANSFERRED STARS!

The Square of Pegasus dominates much of the evening sky during September. It is of characteristic shape, and is extremely easy to find, though it is not actually so bright and striking as might be thought from the maps. The four stars in the Square are Alpha, Beta, and Gamma Pegasi, and – surprisingly – Alpha Andromedæ, better known by its proper name of Alpheratz.

Originally, the constellation boundaries were somewhat arbitrary, and the list of 48 groups given by Ptolemy did not even cover the whole of the sky within range of Alexandria. Various modifications were made, and new groups added. Then, in 1603, the system of Greek letters was introduced by Johann Bayer, another of this year's centenaries; he was born at Rhain, in Bavaria, in 1572, and died in 1625.

Bayer allotted each star a Greek letter, usually beginning with the brightest star (Alpha) and working through to Omega, though the sequence was not always strictly followed. In his catalogue, Alpheratz was included in Pegasus, as Delta Pegasi. Later, for no apparent reason, it was transferred to Andromeda, but certainly it fits in much more logically with Pegasus.

Another similar case is that of Al Nath, now known as Beta Tauri, but formerly as Gamma Aurigæ. Here again there seems little sense in the transfer, because Al Nath seems to belong to the Auriga pattern, and Taurus has no definite shape at all. Yet a third case is to be found in the southern hemisphere, where the former Gamma Scorpii has been re-designated Sigma Libræ.

Bayer's catalogue included 500 stars as well as the 777 which had been listed by Tycho Brahe. It was a valuable contribution, and the Greek letters in use today are those which Bayer allotted. Bayer himself was never a professional astronomer; he was a lawyer, and to him astronomy was an enjoyable hobby.

October

New Moon: 7 October *Full Moon*: 22 October

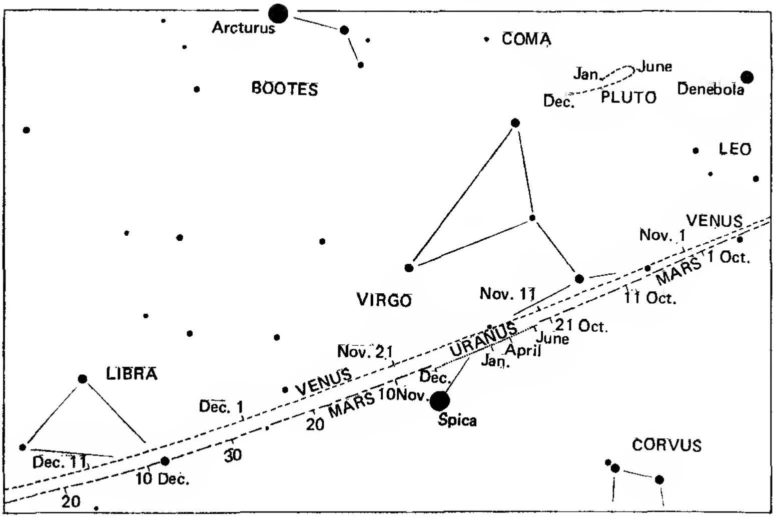
Mercury moves out from the Sun as an evening star, but even at the end of October it is still too far south and too low in the sky to be seen in these latitudes.

Venus is still a brilliant morning star (magnitude −3·7 to −3·5) rising two to three hours after midnight. It is now in Leo, and on the morning of 4 October it may be seen in a dark sky very close to Regulus.

Mars is now a morning star, and by the end of the month it rises in the east about two hours before the Sun. The planet is moving direct in Virgo, but is still only of magnitude +2·0. Mars will be seen very close to Uranus on 31 October, but this conjunction will be difficult to observe in the bright sky at dawn.

Jupiter will be seen in the south at sunset, and sets in the south-west in the late evening. It is still bright enough to be easily recognized, but continues to fade as its distance increases (magnitude −1·7 to −1·6).

Saturn rises in mid-evening to the north of east. It reaches a stationary point on 2 October, between the constellations Orion and Auriga, and its brightness is now increasing rapidly as it approaches opposition (magnitude +0·2 to 0·0).



Venus, Mars, Uranus and Pluto

FIFTEEN YEARS OF SPACE

Fifteen years ago, on 4 October, 1957, the Space Age began. It was started by the launching of the first artificial satellite the Soviet vehicle Sputnik 1, which was of modest size and carried little apart from a radio transmitter, but which will never be forgotten.

The launching was not entirely unexpected, and the U.S. Vanguard Project had been officially under way ever since 1955, but it is true to say that the efficiency of the Russian rockets came as a surprise to everyone in the West. Shortly afterwards, in November 1957, came the much more massive Sputnik 2, while the American programme had been running into serious difficulties; the first projected launching of Vanguard, also in 1957, was a fiasco, and it was not until the following year that an American satellite went into orbit. This was Explorer 1, master-minded by Wernher von Braun. Though it was so small, Explorer proved to be of immense importance, since instruments carried in it detected the now-famous Van Allen radiation zone.

During the fifteen years since Sputnik 1, progress has been quicker than anyone could have expected, and it may be interesting to give a few of the main events of each year:

1957 Sputniks 1 and 2. Beginning of the Space Age.
1958 First American satellite launchings. Van Allen zones discovered.
1959 Three Russian lunar probes, one of which (Lunik 3) sent back photographs of the far side which is always turned away from the Earth.
1960 First weather satellite (Tiros).
1961 First man in space (Gagarin). American sub-orbital flight (Shepard). Unsuccessful Venus probe launched by the Russians.
1962 First American orbital flight (Glenn). Transatlantic television satellite (Telstar). First successful planetary probe (Mariner 2, to Venus).
1963 First manœuvrable satellite (Polyot 1). Two space-craft in orbit at the same time (Nikolayev and Popovich).
1964 Close-range photographs of the Moon (Ranger 7).
1965 First 'space-walk', by Alexei Leonov. Close-range photographs of Mars obtained from Mariner 4. Successful U.S. space-docking.
1966 First soft landing of an automatic probe on the Moon: Russia's Luna 9. First probe to land on Venus (Venera 3), though contact was lost. Improved close-range lunar photographs obtained from the U.S. Orbiters.
1967 First soft landing of a probe on Venus. (Venera 5, U.S.S.R).
1968 First orbital flight of a manned Apollo craft: Apollo 7. First flight round the Moon (Borman, Lovell, Anders: Apollo 8).
1969 Lunar landings: Apollo 11 (July), with Armstrong, Aldrin, Collins: Apollo 12 in November, with Conrad,

Bean, Gordon. Improved close-range photographs of Mars from Mariners 6 and 7.

1970 First Japanese and Chinese satellites. First automatic probe to go to the Moon and back (Luna 16). First 'Moon-crawler' (Lunokhod 1). First probe to send back signals from the surface of Venus (Venera 7).

1971 Further exploration of the Moon, with Apollo 14 (Shepard, Mitchell, Roosa). First space station, Salyut.

It is an impressive list, and there have been remarkably few accidents. the worst were those at Cape Kennedy, involving the deaths of three astronauts (Grissom, White and Chaffee) during a test inside the capsule, and the disaster with Soyuz 1, in which the Soviet cosmonaut Vladimir Kómarov was killed on landing. But now that lunar landings have become almost routine (despite the hair-raising voyage of Apollo 13 in 1970!) it is difficult to recall that as recently as the mid-1950s, America was in no position to launch even a grapefruit-sized artificial satellite.

VENUS AND REGULUS

The close conjunction of Venus and Regulus on 4 October will be interesting to observe. Unfortunately there will be no occultation, and indeed occultations of bright stars by planets are so rare that many astronomers have never had the chance to observe one.

Such an opportunity did occur on 7 July, 1959, again involving Venus and Regulus. In the early afternoon, as seen from Britain, Regulus was occulted. The phenomenon was widely observed, both in Britain and elsewhere, and the fading of Regulus just before immersion gave useful information about the height of Venus' atmosphere, which was not then known accurately (the space-probes still lay years in the future). No readers of this *Yearbook* are likely to see another occultation of Regulus by Venus, since the next will not take place for hundreds of years.

THE MILKY WAY

October evenings present the Milky Way at its best so far as the northern hemisphere is concerned. The glorious, shining band stretches from one horizon to the other, and passes almost overhead in the neighbourhood of Cassiopeia. The dark rifts in the Cygnus area are easily identified even with the naked eye.

There are many legends about the Milky Way, but it was not until the start of telescopic astronomy that its nature was realized. Galileo, soon after he made his first primitive 'optick tube', recorded that the Milky Way is made up of countless faint stars, which seem to be so close together that they almost touch. It is now known that the crowding is merely a line of sight effect. The Galaxy is a flattened system, and when looking along the main plane we see many stars in almost the same direction. The distance of the Sun from the galactic centre was formerly thought to be 25,000 light-years, but astronomers have now decided that 32,000 light-years is probably closer to the truth. We cannot see the actual centre, which lies in the direction of the Sagittarius star-clouds; there is too much interstellar material in the way.

The owner of a pair of binoculars can spend many enjoyable hours in sweeping around the Milky Way area of the sky. Innumerable rich star-fields will come into view, together with clusters and groups of stars. Moreover, most novæ appear in or near the Milky Way, and the few dedicated amateurs who have concentrated upon nova-hunting have been able to make spectacular discoveries. In particular, George Alcock, by profession a schoolmaster in Peterborough, has now found three novæ: one in Delphinus, one in Vulpecula, and one in Scutum, all in the Milky Way region.

JACQUES BABINET

Yet another in the list of this year's centenaries is the French astronomer Babinet, who was born at Lusignan in 1794, and died in Paris on 19 October, 1872. He was interested in computing the orbits of comets, and advanced serious objections to the then-popular Nebular Hypothesis of Laplace. For a time he held professorships first at Poitiers, and then at Collège de France.

November

New Moon: 6 November *Full Moon*: 20 November

Mercury is at greatest eastern elongation (23°) on 5 November, but is then well south and too low in the sky to be seen in the evening twilight. Mercury is in inferior conjunction on 26 November.

Venus rises about 4^h to 5^h in the east in a dark sky. It is still a brilliant object (magnitude −3·5 to −3·4) although it has now faded considerably. Venus passes about a degree north of Uranus on 16 November, and four degrees north of Spica on 17 November (see diagram on page 98).

Mars is also in Virgo, and rises about two hours before the Sun. It passes three degrees north of Spica on 4 November and moves into Libra at the end of the month. Mars now begins to grow a little brighter (magnitude +2·0 to +1·9).

Jupiter is to be seen low in the south-west in the early evening, setting about two hours after the Sun. Magnitude −1·6 to −1·5.

Saturn is now moving retrograde in Taurus and grows even brighter (magnitude 0·0 to −0·2). It rises north of east about two hours after sunset at the beginning of November, and the dark skies afford an opportunity of observing the planet and its splendid rings with a small telescope. The largest satellite, Titan, may also be seen with quite a small glass, but the other satellites need much larger instruments.

VESTA

At the end of the month Vesta, the brightest member of the swarm of minor planets, is in opposition. However, it is not at its best. At times it can just reach naked-eye visibility, but this year the maximum magnitude will be only 6·6, so that it will be invisible without optical aid.

Vesta was the fourth asteroid to be discovered, but is considerably brighter than its predecessors – partly because it is closer to the Sun and to the Earth. Details of the first four minor planets are as follows:

	Mean distance from Sun miles	*Sidereal period years*	*Maximum magnitude*
Ceres	257,000,000	4·6	7·4
Pallas	257,400,000	4·6	8·0
Juno	247,800,000	4·4	8·7
Vesta	219,300,000	3·6	6·0

But as well as being closer than the first three asteroids, Vesta was also assumed to have a higher albedo or reflecting power. The official diameters of the four were 427 miles for Ceres, 280 for Pallas, 241 for Vesta and 150 for Juno. Then, in 1970, D. A. Allen carried out some infrared research, and announced that the diameter of Vesta was not a mere 241 miles, but as much as 370. This makes it the largest member of the swarm apart from Ceres, and means that its albedo becomes more normal.

Of the other asteroids, No. 10, Hygeia (diameter, 220 miles) exceeds Juno; but Hygeia is, on average, 292,600,000 miles from the Sun, and never become brighter than magnitude 9·5.

THE STAR OF 1572

On 11 November four hundred years ago, a young Dane named Tycho Brahe noticed a brilliant new star in the constellation Cassiopeia. In his own words:

> 'In the evening, after sunset, when, according to my habit, I was contemplating the stars in a clear sky, I noticed that a new and unusual star, surpassing all the other stars in brilliancy, was shining almost directly above my head; and

> since I had, almost from boyhood, known all the stars of the heavens perfectly (there is no great difficulty in attaining that knowledge), it was quite evident to me that there had never before been any star in that place in the sky, even the smallest, to say nothing of a star so conspicuously bright as this . . . A miracle indeed, either the greatest of all that have occurred in the whole range of nature since the beginning of the world. or one certainly that is to be classed with those attested by the Holy Oracles.'

Tycho observed the star through to March 1574. At its best it was about as brilliant as Venus, and could be seen in daylight. Slowly it faded, and Tycho, who was an enthusiastic astrologer as well as an astronomer, did not fail to point out the moral:

> 'The star was at first like Venus and Jupiter, giving pleasing effects; but as it then became like Mars, there will next come a period of wars, seditions, captivity and death of princes, and destruction of cities, together with dryness and fiery meteors in the air, pestilence, and venomous snakes. Lastly, the star became like Saturn, and there will finally come a time of want, death, imprisonment and all sorts of sad things.'

Tycho's fears did not come true. The star was in fact a supernova, one of only four which have been seen in our Galaxy since the start of recorded history. As soon as it faded below the sixth magnitude it was lost to view; telescopes had not then been invented. It cannot now be located optically, and must be fainter than magnitude +18, but it is thought that a radio source in the appropriate position is probably associated with the old supernova.

Supernovæ are of two classes. Type I attains a maximum luminosity of perhaps 200,000,000 times that of the Sun. Stars of type II are less extreme, but may still have a peak output

20,000,000 times that of the Sun. It is unfortunate that they are so rare; the last to be seen in our Galaxy was Kepler's Star of 1604, only a few years before the invention of the telescope. Tycho himself had died in 1601. His astronomical career had been outstanding; the enthusiasm kindled by the supernova of 1572 never left him, and the catalogue of stars which he drew up at his island observatory of Hven, between 1576 and 1596, was of amazing accuracy. It was not surpassed for over a century.

Supernovæ can be detected in other galaxies, but are usually faint. The main exception was S Andromedæ, the name given to the supernova which appeared in M.31, the Andromeda Spiral, in 1885. It became almost bright enough to be visible with the naked eye, but it subsequently faded into invisibility, and all trace of it has long since been lost. At the time, astronomers were by no means certain that it lay inside the Spiral – and in any case it was generally thought that spirals were members of our Galaxy rather than independent, external systems.

It is impossible to predict when the next supernova will appear in our Galaxy, though by the law of averages it seems to be well overdue! Scientists would welcome the chance to study a galactic supernova by means of modern equipment, but the opportunity may not come for a long time.

The most famous supernova remnant is the Crab Nebula in Taurus, M.1. This is the débris of the brilliant supernova seen in the year 1054 by Chinese and Japanese astronomers. It was probably superior even to Tycho's Star, and is one of the most interesting objects in the sky; it is a radio source, and also emits X-radiation. Moreover, it contains the only pulsar to be optically identified as yet. Tycho's Star has left no comparable gas-cloud, and there are reasons for thinking that the Crab Nebula star was exceptional even by the 'conventional' standards of supernovæ.

December

New Moon: 5 December *Full Moon*: 20 December

Solstice: 21 December

Mercury is at greatest western elongation (21°) on 14 December, and as it is then in high northern declination, it may be possible to catch a glimpse of the planet low down in the south-east just before dawn.

Venus continues as a brilliant morning star (magnitude −3·4) and by the end of the year it rises south of east about two hours before the Sun. The planet's direct motion is now quite rapid, and it overtakes Mars again on 3 December (see diagram on page 98) near the third-magnitude star Alpha Libræ (Zuben-el-Genubi). The planet passes some degrees north of Antares on 25 December.

Mars is a morning star in Libra, rising south of east about three hours before the Sun. The conjunction with Venus on 3 December is mentioned above. (Magnitude of Mars +1·9 to +1·7.) The opposition of Mars in 1973 will be almost as favourable as that of 1971, and the planet will then be in Pisces and will reach magnitude −2·2.

Jupiter sets an hour or so after the Sun, and may be seen in the south-west in the evening twilight. The planet is approaching conjunction, but it will be noticed that there is no conjunction of Jupiter in 1972, the synodic period of the planet being about 13 months.

Saturn is at opposition on December 9, and reaches magnitude −0·3. At this time the planet is about 750 million miles from the Earth (1200 million km.) and the rings are opened almost to their widest extent — about 27 degrees. The rings contribute very largely to the brightness of the planet, and when widely open, as at this opposition, they make a difference of more than a whole magnitude. Compare the brightness of Saturn at this opposition with that in 1966, when the rings were seen edge-on to the Earth and the magnitude was only +0·8.

REPORTED FAINT RINGS OF SATURN

Saturn, at opposition this month, is splendidly placed for observation from Britain and the United States. Not only is it well to the north of the celestial equator, and therefore high in the sky, but the rings are almost at their maximum opening. The northern hemisphere of the planet is partly covered, so that the south equatorial belt is displayed.

In 1907 G. Fournier, in France, reported a new dusky ring outside Ring A. This was provisionally named Ring D. It has been reported again from time to time, but its existence has never been proved, and many astronomers are distinctly sceptical about it, though there is no theoretical objection to its existence.

Much more recently, P. Guérin, using the 24-inch refractor at the Pic du Midi Observatory, has taken photographs which, it is said, show another dusky ring, inside Ring C (the Crêpe Ring). According to Guérin, the new ring – also, rather confusingly, called Ring D – is weaker than C; it is separated from C by a dark division, similar to Cassini's Division; and it extends almost as far as the globe of Saturn. Its light decreases nearer the globe, and is equal at the border of the ring to 1/18th of the maximum brightness of Ring B in the neighbourhood of Cassini's Division.

Whether the Guérin ring can be regarded as definite is a matter of opinion, but a least there is more evidence in its favour than with the Fournier ring, and further careful studies will no doubt be able to provide a positive answer.

THE PLEIADES

Without doubt Messier 45, known universally as the Pleiades and unofficially as the Seven Sisters, is the finest open cluster in the entire sky. It is excellently placed for observation during evenings in December, and most people will be able to recognize it. Certainly it is difficult to overlook. At first glance it seems like a patch of hazy luminosity in the sky, not very far from the bright orange star Aldebaran; closer inspection reveals that there are individual stars. The leader, Alcyone or Eta Tauri, is of the third magnitude.

The Pleiades have been known since very early times, and are referred to by both Homer and Hesiod. They are also mentioned in the Bible. In more modern times, they were listed by Messier in his famous catalogue of clusters and nebulæ (1781). In 1845 Johann von Mädler, best known as one of the greatest pioneer observers of the Moon, suggested that Alcyone might be the centre of the galactic system, so that the Sun and all other stars revolved round it; the idea was current for a brief period, but was based on no reliable evidence, and was soon abandoned.

The cluster is 410 light-years away, and according to the Swedish astronomer Åke Wallenquist the diameter of the cluster is 22 light-years. Altogether there are roughly 500 stars, together with a beautiful reflection nebula well seen only in long-exposure photographs taken with large telescopes. The leading stars are hot and of early spectral type, and the cluster is young; estimates of its age vary, and range between 20 million years (according to the late W. Baade) up to around 150 million years.

The following are the brightest stars in the cluster:

Name		*Magnitude*	*Spectrum*
Alcyone	Eta Tauri	2·9	B7
Atlas	27 Tauri	3·6	B8
Electra	17 Tauri	3·7	B6
Maia	20 Tauri	3·9	B7
Merope	23 Tauri	4·2	B6
Taygete	19 Tauri	4·3	B6

Name		*Magnitude*	*Spectrum*
Pleione	28 Tauri	5·1	B8 pec
	HR 1172	5·5	B8 (Near the edge!)
Celæno	16 Tauri	5·5	B7
	18 Tauri	5·6	B8
Asterope	21 Tauri	5·8	B8

There are a dozen more stars above the seventh magnitude. The main group, made up of Alcyone, Electra, Atlas, Merope, Maia, Taygete Pleione, and Asterope has been compared to a tiny, very distorted Plough, though the resemblance is not very marked.

It is interesting to see how many Pleiades are visible with the naked eye. Most people with average sight can see seven, but keen-eyed observers can see more. Apparently the record is held by the last-century German astronomer Heis, who could count nineteen; but anyone who can glimpse twelve is doing very well indeed.

Pleione is an interesting 'shell star', and is unstable; it is in very rapid rotation, and may spin about a hundred times more quickly than the Sun, in which case it will be a very flattened body. There is an old legend according to which one of the 'Seven Sisters' has faded away, but although it has been suggested that Pleione may have been brighter in ancient times than it is now there is not much real support for such a theory.

The Pleiades show up magnficiently in binoculars, and with a telescope many more members of the cluster come into view. (Even Galileo, in 1610, counted three dozen.) However, a very wide field is necessary; with higher powers and a smaller field, the full beauty of the spectacle is lost. It has been said that with a large telescope, the Pleiades are best seen in the finder! The cluster makes an ideal object for photography.

ANOTHER ANNIVERSARY

Venus is still brilliant in the morning sky. By now we know a great deal about it, though its mysteries remain. The first positive information was sent back ten years ago – by the U.S. probe Mariner 2, which by-passed the planet in December 1962. Again it is amazing how much progress has been made in space research in a period of only a decade.

Eclipses in 1972

In 1972 there are four eclipses, two of the Sun and two of the Moon.

(1) *An annular eclipse of the Sun* on January 16, the central path lying entirely in Antarctica, but visible as a partial eclipse in the extreme south of South America at sunrise, and in the south-west of Australia at sunset.

(2) *A total eclipse of the Moon* on January 30, visible in Australasia, the Pacific Ocean and the greater part of North America. The eclipse begins at 9^h 12^m G.M.T. and is total from 10^h 35^m to 11^h 12^m G.M.T.

(3) A *total eclipse of the Sun* on July 10 with a maximum duration of 2 min. 35 sec. The central path crosses the Bering Strait, Alaska, Northern Canada, New Brunswick, Prince Edward Island and Nova Scotia to end in the Atlantic Ocean. Visible over the greater part of North America as a partial eclipse. In the British Isles a partial eclipse may be seen just before sunset. At Greenwich the eclipse begins at 19^h 34^m and reaches a maximum at 20^h 18^m, when about 50 per cent of the Sun's disk will be covered by the Moon, but sunset here occurs at 20^h 13^m, just before the maximum phase is reached. At Edinburgh these events occur about four minutes earlier, but sunset here is at 20^h 42^m, so that the maximum phase will be seen.

(4) *A partial eclipse of the Moon* on July 26, about 55 per cent of the Moon's disk being covered by the Earth's shadow at maximum. Visible in New Zealand, Antarctica, the Pacific Ocean and the greater part of the Americas. The eclipse begins at 5^h 55^m, reaches its maximum at 7^h 16^m and ends at 8^h 36^m G.M.T.

Occultations in 1972

In the course of its journey round the sky each month, the Moon passes in front of all the stars in its path and the timing of these occultations is useful in fixing the position and motion of the Moon. The Moon's orbit is tilted at more than five degrees to the ecliptic, but it is not fixed in space. It twists steadily westwards as a rate of about twenty degrees a year, a complete revolution taking 18·6 years, during which time all the stars that lie within about six and a half degrees of the ecliptic will be occulted. The occultations of any one star continue month after month until the Moon's path has twisted away from the star but only a few of these occultations will be visible at any one place in hours of darkness.

There are only four first magnitude stars that can be occulted by the Moon; these are Regulus, Aldebaran, Spica and Antares.

In 1972 Antares will be occulted each month, and two of these events will be visible in the British Isles. On May 1 the Moon, two days past the full, will occult Antares in the early morning hours (between 3^h and 4^h). On September 14 the occultation will occur in daylight (15^h), the Moon being then almost at First Quarter.

The occultation of fainter stars is seldom of great interest to the casual observer, but the event of March 19 deserves attention. The young Moon, only four days old, will pass in front of many of the stars of the Pleiades group in the evening between 19^h and 22^h.

The planets Mercury, Venus, Mars and Jupiter will also be occulted by the Moon during 1972, and the occultation of Mars on May 15 will be visible in the British Isles. The crescent Moon, about three days old, will occult Mars at 20^h 44^m, and the planet will reappear at 21^h 02^m. All times are G.M.T.

Comets in 1972

The appearance of a bright comet is a rare event which can never be predicted in advance, because this class of object travels round the Sun in an enormous orbit with a period which may well be many thousands of years. There are therefore no previous records of the previous appearance of these bodies, and we are unable to follow their wanderings through space. The comets of short period, on the other hand, return at regular intervals, and attract a good deal of attention from astronomers. Unfortunately they are all faint objects, and are recovered and followed by photographic methods using large telescopes. Most of these short-period comets travel in orbits of small inclination which reach out to the orbit of Jupiter, and it is this planet which is mainly responsible for the severe perturbations which many of these comets undergo. Unlike the planets, comets may be seen in any part of the sky, but since their distances from the earth are similar to those of the planets their apparent movements in the sky are also somewhat similar, and some of them may be followed for long periods of time. As a result comets are more commonly observed than is generally supposed. For example, in 1970, which was something of a record year, no less than 25 comets were under observation, two of which reached naked-eye brightness. Fourteen of the others were short-period comets, the returns of twelve of these having been predicted in advance.

The following short-period comets are among those most likely to be seen in 1972.

Comet Grigg-Skjellerup has a period of only 4·9 years, and its orbit is inclined at nearly 18 degrees. Discovered in 1902, it was recovered in 1922 and has made eleven appearances in all, the last being for a short time in 1966.

Comet Tempel (2) was first seen in 1873, and has been observed at 14 returns. It has the short period of 5·3 years, and was extensively studied in 1967–8 when it was visible for nearly a year and reached a magnitude of 8·4.

Comet Holmes was first discovered in 1892, and was seen again in 1899 and 1906. It was then lost for many years, but was recovered in 1964 as a result of a new prediction – an example of the use of modern electronic computers in the recovery of several 'lost' comets. Comet Holmes has a period of 7·4 years and is inclined nearly 20 degrees to the ecliptic.

Comet Giacobini-Zinner was first seen in 1900 and has been shown to be the comet responsible for the Draconid meteor shower of October. It has been observed at eight returns, the last in 1965 being only a very brief appearance. The period is 6·4 years, and the orbit has the high inclination of 31 degrees.

Comet de Vico-Swift is the second of the 'lost' comets to be studied by modern computer methods. It was seen in 1844 and 1894, and has also been identified with the comet of 1678. As a result of new calculations it was recovered after the lapse of seventy years in 1965 and was followed for several months. It is expected to return at the end of 1971. The period of this comet is 5·1 years, and it has the very small inclination of less than four degrees.

Comet Väisälä (1) is a comet with the longer period of 10·5 years. It was followed for several months in 1959–60, and a new calculation suggested that it should return to perihelion at the end of 1971. It was, in fact, recovered by Dr Elizabeth Roemer at the end of 1970, using the 90-inch reflector at Kitt Peak, Arizona. The magnitude at recovery was given as 21, and clearly only a very large telescope could possibly deal with so faint an object.

Comet Schwassmann-Wachmann (1) has a nearly circular orbit with a period of 16·1 years, which lies entirely between the orbits of Jupiter and Saturn. It behaves very much like a planet and is visible each year. This comet is remarkable because it undergoes changes of brightness, which seem to have some connection with solar activity.

Meteors in 1972

Meteors ('shooting stars') may be seen on any clear moonless night, but on certain nights of the year their number increases noticeably. This occurs when the Earth chances to intersect the orbit of a meteor swarm, which is a concentration of meteoric dust moving in an orbit around the Sun. Such an intersection can occur only at one particular time of year, but if the dust is spread out along the orbit, the resulting shower of meteors may last for several days.

The following table gives some of the more easily observed showers, with their radiants; the effect of moonlight in 1972 is indicated.

Limiting dates	*Shower*	*Maximum*	*R.A.*	*Dec.*	*Range*
Jan. 3–4	Quadrantids	Jan. 3	$15^{h}\,28^{m}$	$+50^{\circ}$	
April 20–22	Lyrids	April 22	$18^{h}\,04^{m}$	$+33^{\circ}$	
July 27–Aug. 17	Perseids	Aug. 12	$3^{h}\,04^{m}$	$+58^{\circ}$	
Oct. 15–25	Orionids	Oct. 20–21	$6^{h}\,24^{m}$	$+15^{\circ}$	M
Oct. 26–Nov. 16	Taurids	Nov. 1–7	$3^{h}\,36^{m}$	$+14^{\circ}$	
Nov. 15–17	Leonids	Nov. 16	$10^{h}\,08^{m}$	$+22^{\circ}$	
Dec. 9–14	Geminids	Dec. 13	$7^{h}\,28^{m}$	$+32^{\circ}$	
Dec. 20–22	Ursids	Dec. 22	$14^{h}\,28^{m}$	$+76^{\circ}$	M

M = moonlight interferes

Minor Planets in 1972

Although there are many thousands of minor planets, only about 2000 have well-determined orbits, and are listed in the catalogues. Of these, only the 'big four', Ceres, Pallas, Juno, and Vesta can reach any considerable brightness; Vesta can occasionally be seen with the naked eye at a favourable opposition. In 1972, however, Vesta only reaches magnitude 6·6 at opposition on 30 November. Ceres, at opposition on 5 February, is a little brighter at magnitude 6·4, but Juno is of magnitude 9·5 at opposition on 1 April. There is no opposition of Pallas during the year.

Some Events in 1973

ECLIPSES

In 1973 there will be four eclipses, three of the Sun and one of the Moon.

4 January. An annular eclipse of the Sun visible only in the southern hemisphere.

30 June. A total eclipse of the Sun, the central track running from South America, across northern Africa to end in the Indian Ocean. In North Africa the maximum duration is about seven minutes.

10 December. A small partial eclipse of the Moon, visible in the British Isles and North America.

24 December. An annular eclipse of the Sun, visible in South America and northern Africa. Visible as a partial eclipse in Great Britain.

THE PLANETS

Mercury will most easily be seen as an evening star at eastern elongation on 25 February and as a morning star at western elongation on 8 August.

Venus will be a morning star in the first few months of the year, and after conjunction in April will be seen as an evening star, coming to greatest elongation on 13 November.

Mars will be at opposition on 25 October in Pisces — a very favourable opposition, although the planet will not be quite as close as in 1971.

Jupiter will be at opposition in Capricornus on 30 July.

Saturn will again be well placed at opposition on 23 December on the border of Taurus and Gemini, and the rings will then be wide open.

Uranus is at opposition on 11 April in Virgo.

Neptune will be in Scorpius at its opposition on 27 May.

PART TWO

Article Section

Again, as in previous *Yearbooks*, we have endeavoured to include ‘something for everybody’. Colin Ronan contributes an historical article, in honour of Johannes Kepler, who was born four hundred years ago; Howard Miles deals with fireballs, C. A. Cross with the far side of the Moon (now well mapped for the first time), and W. M. Baxter contributes an article on the present solar cycle, which is certainly a strange one. Stellar matters are discussed by Iain Nicolson and Martin Cohen, leaving practical matters of telescopes and observatories to F.R. Spry and Henry Wildey. Biographical notes on our contributors are to be found on page 212.

Johannes Kepler (1571-1630)

COLIN A. RONAN

On 27 December 1571, Johannes Kepler was born in the small town of Weil der Stadt in what today is Eastern Germany. He was a premature baby, and a delicate, sickly child; and when he was four, he was nearly blinded by an attack of smallpox. The burden of ill health dogged him throughout his life, to which was added discord at home and, in the world outside, the religious strife which was the legacy of the Reformation and the military confrontations that culminated in the Thirty Years War. His father seems to have enjoyed military service, and was often away on campaigns, while his mother was a restless, quarrelsome, superstitious woman; so much of the responsibility for the boy's welfare fell on his grandparents.

In spite of this unpromising background, Kepler did well at school and showed a lively interest in astronomy allied to a strong leaning towards the Ministry. In due course he entered a Lutheran seminary and, later, went on to Tübingen University. It was here he met Michael Mästlin, the professor of mathematics and astronomy, who was to have a profound influence on his future. Mästlin favoured the Copernican system, but hesitated to support it openly, since the Protestants attacked it on Scriptural grounds. Nevertheless, he inspired Kepler's lifelong fidelity to the theory of a moving Earth orbiting about the Sun, even though such observational evidence as there was militated against it. But Kepler's adherence to the theory in spite of lack of evidence should not surprise us when we realize that his support was mainly stimulated by mystical considerations and by what he felt was a greater geometrical elegance in the new hypothesis.

This æsthetic approach was an integral part of Kepler's outlook. He had a passionate and unshakeable belief that the heavens echoed those harmonious relationships which he was sure were characteristic of a divinely constructed universe. When in 1594 he moved to Graz, not as a pastor, but as a mathematics teacher – for his religious outlook did not fit in perfectly with strict Lutheran orthodoxy – he pursued this concept of celestial harmony and wrote the *Mysterium Cosmographicum* (The Mystery of the Cosmos), his first important book on the subject. Published in Tübingen in 1596 with Mästlin's help, it is a surprising work and, although it now has little astronomical meaning, its pages contain the first serious attempt to explain why the planets must follow the Copernican system and no other.

Kepler's theory was based on two assumptions that seemed well-founded, and were certainly universally accepted. The first was that the planets all orbited in circles, their actual motion being represented by considering each planet fixed on the rim of a circle (an epicycle), the centre of which moved round the rim of a second circle (the deferent). This system, with the Earth near the centre of all the deferents, had been used by the Greek astronomer Ptolemy in the second century A.D., and Copernicus had continued with it, putting the Sun in place of the Earth. The second assumption was that the planets were carried round by completely transparent spheres, each sphere having a deferent of sufficient thickness to contain however many epicycles were necessary to account for the observed motion. This, again, had been adopted by Copernicus. What Kepler did that was novel, was to give a reason why the planetary spheres were of the size which observation indicated.

At this time the diameter of a sphere was calculated from its circumference, and the length of the circumference was determined by the time a planet took to complete one orbit round the Sun. Kepler took the accepted diameters and showed that the 'regular' solids of Greek geometry (solids in which all faces are equal and have the same angles between them) fitted neatly inside the different planetary spheres. For instance, between the spheres of Saturn and Jupiter he found a cube would fill the space, while between Jupiter and Mars a tetrahedron was needed. The gap between the tetrahedron and the cube was the thickness of Jupiter's sphere, and contained just the epicycles needed to account for Jupiter's observed motion.

The use of the regular solids gave Kepler particular satisfaction because he felt that here was something beautiful enough to be part of the divine harmony lying behind the universe, and his book was welcomed by astronomers with a philosophical turn of mind. Indeed, Tycho Brahe, who had made the most accurate measurements of planetary positions then achieved, thought so highly of it that he invited Kepler to work with him. At the time Tycho was in Germany, having been expelled from his observatories on the island of Hven for social and political reasons, while for his part, Kepler was unable to accept the invitation. However, within the next four years, religious persecution in Graz increased so much that Kepler, his wife and step-daughter were finally driven out of the city and in 1600 he joined Tycho, who was now Imperial Mathematician in Prague.

Tycho had never accepted the Copernican theory, and had developed one of his own that was a compromise between the heliocentric hypothesis and the old geocentric one of Ptolemy. He wanted Kepler to study his observations of Mars because these were the most extensive he had made, and he believed that when analysed mathematically they would prove the Copernican hypothesis untenable and his own compromise theory correct. But in the event, his hopes were not realized: the observations led Kepler to quite other conclusions, but these Tycho did not live to see because he died in October 1601, long before any definite results could be reached. Kepler was appointed Tycho's successor and, true to his promise, continued to concentrate his efforts on the orbit of Mars which, fortunately, has a comparatively eccentric orbit and would show most clearly of all the planets whether or not Tycho's theory was correct. But try as he would, Kepler could not fit the observations to the compromise system, and he turned to the Copernican theory. Here things went better, but still not perfectly; and it was not until April 1605 that Kepler suddenly realized that the stumbling block was not the heliocentric theory but Copernicus' use of circular orbits. Mars, he found, did not move in a circular path, but in an ellipse.

Further computation showed that the orbit was an ellipse with the Sun at one particular point or 'focus' – his first 'law' of planetary motion – but also that the planet did not move at a regular speed as everyone had previously believed. Instead it travelled most quickly when close to the Sun and most slowly when furthest away. Precisely how fast it moved at intermediate points was difficult to determine, but Kepler found that by dividing the orbital path into a large number of small straight lines he could calculate an answer. It then seemed that if one took a line from the Sun to the planet, this line would sweep out equal areas within the ellipse in equal times. Kepler always regarded his second 'law' as convenient but not exact, and it never received wide acceptance like his first 'law' until well after the publication of Newton's *Principia* in 1687.

The results for Mars were published in 1609 in a book which Kepler called *Astronomia Nova* (The New Astronomy), but only comparatively few copies were printed and it was not widely read, even among scholars, as its text was complicated and it took the still unpopular Copernican system for granted. But in March the year after its appearance, Galileo's important *Siderius Nuncius* (The Sidereal Messenger) was published, giving details of observations with the newly invented telescope – observations that Galileo claimed supported the Copernican theory. Renewing a desultory correspondence, started when Kepler published his *Mysterium Cosmographicum,* Galileo sent him a copy with a request for comments. Kepler, who had no telescope, nevertheless complied at once and his reply supporting Galileo's results appeared in a new edition of *Siderius Nuncius* a few months later. And the whole episode stimulated Kepler to turn his attention back to optical problems. Six years earlier he had written a book on optics with special reference to atmospheric refraction and other visual effects in observing, but now he concentrated on lenses and lens combinations, giving his own version of the refracting telescope and explaining how a third lens could give an erect image. This book, called *Dioptrice* (Dioptrics), appeared in 1611 and, like *Astronomia Nova* it attracted little attention; Kepler returned to his planetary studies.

But the lack of outside interest in yet another book was the least of Kepler's worries in 1611, for his salary was not fully paid, his wife and son died, and there was civil war in Prague, so that he was forced to move once more, and he went to Linz where, in 1612, he married again. But misfortune still dogged him. Because of his lack of dogmatism he had been excommunicated from the Lutheran Church, and although he obviously derived comfort when he remarried, things were not easy socially or financially. Then, in 1618, there came another bitter blow when his mother was put on trial as a witch, a trial that dragged on over the next three years until, at last, he managed to exert enough influence to have the proceedings closed.

In some ways Kepler's planetary work must have acted as a refuge in a world torn by hatred and turmoil, especially as he was able to make substantial progress, for he found that the two laws of motion he had formulated for Mars applied also to the other planets. But Kepler went further than this, for in 1618 while pursuing his search for the divine plan of the cosmos, he had discovered his third 'law' of planetary motion connecting the periods of the planets and their average distances from the Sun. However, this seemed to him less significant than the investigation of which it was merely a part, the development of a new insight into the harmony of the universe. Nevertheless, his friends persuaded him to include the new law and re-write his *Astronomia Nova* so that it would be understood by as wide a readership as possible, and Kepler met their demands as well as satisfying his own wishes, by writing two books. His planetary laws he incorporated in the *Epitome Astronomiæ Copernicæ* (Epitome of Copernican Astronomy) which appeared piecemeal in 1618, 1620, and 1621, and included suggested physical explanations for planetary motion. The book was not free of mysticism but, by and large, it was an important scientific treatise, yet to Kepler it was nothing compared to his other book *Harmonices Mundi* (Harmony of the World), which was begun in Graz but only finished and published in 1619. This was a completion of what he had begun long before in *Mysterium Cosmographicum,* and contained his new discovery of celestial harmony, found by taking the speed of the planets when nearest and furthest from the Sun and working out the musical notes their numbers generated, and then expressing these on a musical scale.

In 1626 Kepler was driven from Linz and moved first to Ulm and then to Regensberg, where he died in November 1630. It was in Regensberg that he wrote his *Somnium* (Dream) – an imaginative argument by lunar inhabitants to prove their world was immovable and used by Kepler to parody the contention that the Earth was fixed in space – and the important *Tabulae Rudolphinœ* (Rudolophine Tables) which were based on Tycho's observations and gave stellar and planetary positions, and did service for more than a century after. Yet it was Kepler's own belief that the *Harmonices Mundi* was his most significant contribution, and although it is easy now to criticize him for this, for his belief in some aspects of astrology, and for the mysticism that made him see the universe as a living soul – the celestial counterpart of man – it must be remembered that he lived in the different intellectual climate of the Renaissance. Then, the mythical golden age of the classical world was very real, and almost every scholar had a foot in both camps, the ancient and the modern. For all his brilliance, Kepler was a child of his times, and the wonder is not that he failed to shed all the errors of his age, but that in spite of them he managed to achieve so much.

Fireballs

H. G. MILES

It was only just over 150 years ago that leading scientists were arguing about the feasibility of stones falling from the sky. Either they did not believe that it was possible or said that the stones had come from some volcanic eruption. In contrast it did not seem to present a problem to the many people who, throughout the centuries, had actually witnessed such events! As late as 1790, the famous scientist Lavoisier declared that writings which described such beliefs were apocryphal. Nevertheless, a rapid conversion to the acceptance of the fact that stones could fall from the sky occurred soon after an incident which took place at L'Aigle, France, in 1803.

Meteorites are exceptionally important and are the subject of intense research, because, until recently, they were the only source of non-terrestrial rocks available for study. Unfortunately, before any rock can reach the surface of the Earth, it has to survive the passage through the atmosphere. The frictional heat developed is so intense that in most cases the whole rock is vaporized, this process being seen as a brilliant fireball streaking across the sky. The small percentage of the objects that still exist in a solid state after they have lost their cosmic speed produce meteorites which fall more or less vertically through the lower regions of the atmosphere. These meteorites can weight from just a few grammes to many thousand kilogrammes, but in all cases they represent only a small fraction of the total mass which originally had an existence completely independent of the Earth.

It has been found convenient to divide meteorites into two classes according to the circumstances which led to the discovery of the object. A *fall* is defined as an object which has been located because the event was witnessed, but a *find* is one which has been identified by its visual appearance, it possibly contrasting strongly with the appearance of surrounding rocks. One would therefore expect that a large percentage of the *finds* to be of types which are fairly resistant to erosion, and this is borne out by the fact that a large fraction of *finds* are of the iron-nickel variety. Even after a few weeks, the fragments of the stones from the Barwell meteorite fall in December, 1965, showed much evidence of erosion. The event was of course a *fall,* but even so, it is doubtful that the stones would have been recognized as a find because of the similarities in appearance with local rocks.

It is therefore important that one finds meteorites as quickly as one can after they arrive. Unless they are seen to fall it is essential to determine the track of the fireball so that the fall area can be located. A study of the fireball is of interest in its own right because if sufficient information is forthcoming, it may be possible to determine the orbit of the object prior to entering the Earth's atmosphere. Unfortunately it is impossible to predict the appearance of a fireball – so that when one does occur, it is only by luck that one is fortunate enough to witness such an event.

From earliest times, whether by legends or writings, we learn of 'fiery messengers from space'. The city of Waqar in Arabia is said to have been destroyed by fire from heaven. The region surrounding the meteorite craters at Henbury, Australia, is tabu to the aborigines, who refer to the area as, when translated, 'sun walk fire devil rock'. The fanlike markings found on the ceiling of a cavern at Altamira are thought to be a record of an outstanding meteor shower, i.e. particles about the size of grains of sand being burnt up by frictional heat as they rush into the atmosphere. In recent years much interest has been centred on the 'Divine Fireball' portrayed in Raphael's *Madonna di Foligno,* painted in 1512.

The important event which triggered the surge of interest in meteoritics occurred at L'Aigle in France on 26 April, 1803.

Many people witnessed a brilliant fireball travelling approximately north-eastwards across northern France round about midday. Some time after its passage loud detonations were reported, and appeared to originate from an isolated black cloud in an otherwise clear sky. Associated rumblings were said to have lasted for over five minutes. Shortly afterwards thousands of stones were reported to have fallen over an area measuring 11 by 4 kilometres near to L'Aigle. The largest stone recovered weighed just over 10 kg. The full reports of the incident removed all doubt that it was possible for stones to come from outer space, and from that time the significance and importance of these objects were fully appreciated in the scientific community.

Many references to fireballs seen over this country can be found in historical records, but only a few have been related to known meteoritic falls. On 13 December, 1795, a stone weighing about 120 kg was seen to fall at Wold Cottage, near Scarborough, about 10 metres from a workman. In this case no fireball was seen nor any sound effects heard by the workman, but as is often the case detonations were heard in surrounding villages. The iron which fell at Rowton in Shropshire in 1876 was also accompanied by severe sonic booms. The absence of reports of a fireball can often be attributed to the possibility of thick cloud cover at the time, a situation which is by no means uncommon in these islands! The fall at Appley Bridge, Wigan, Lancashire, on 13 October 1914, was, however, preceded by a brilliant fireball travelling in a north-north-westerly direction over the north Midlands, and was seen by many people in Lancashire and Cheshire. After a short time, a sonic boom was heard, followed by prolonged rumblings.

Excluding the very small particles, all bodies, on entering the Earth's atmosphere, will glow through frictional heat. This heating is severe and most objects will be vaporized completely long before reaching the denser regions of the atmosphere. Particles associated with meteor streams are generally very small and on entering the atmosphere are seen to move across the sky at a high speed and then suddenly go out. These so-called 'shooting stars' vary considerably in appearance, some being bluish in colour, others yellow. Some just fade out, whilst others seem to explode at the end point. Some leave a trail behind which fades rapidly, but with others the trail fades quite slowly. Some shed sparks during the whole of their journey across the sky.

In addition to the 'shower meteors', which are seen at certain times in the year and seem to originate from fixed points in the sky, called the radiant, one sees 'sporadic' meteors, which as their name suggests, do not seem to have any preferred direction or radiant. They vary in appearance in a similar way to the stream meteors. Occasionally an extra bright object, often reddish in colour, appears to sail majestically from one side of the sky to the other. These objects are generally larger than those producing the normal meteors, and can be considered as the dividing line between what are called fireballs and meteors. This boundary is quite arbitrary, but is convenient in many respects. As a general guide, the object is called a fireball if it is brighter than Venus.

This century has seen two extraordinary fireballs, both of which were visible over the Soviet Union. The first occurred on 30 June 1908, and was seen over the Tunguska region of Central Siberia. The reports from eye-witnesses indicate that a fireball of great size and brilliance travelled across the sky in an approximately north-westerly direction. One witness said that, on hearing a bang, he turned round to see an elongated flaming object flying through the sky. He said that the front part was much broader than the tail end, and its colour was like fire in the daytime. He went on to say that the object was many times bigger than the Sun, but not as bright, because he was able to look at it without hurting his eyes. Behind the fireball was a trail of dust which was 'wreathed in little puffs'. He went on to say that blue streamers were left behind from the flames. Another eye-witness, positioned more or less directly under the path of the fireball, experienced scorching of his ears due to the radiant heat from the bolide as it passed overhead. Another witness from the same area described how, as he looked north, the sky was split into two, with the whole of the northern part of the sky filled with fire. The heat from the explosion was so intense that he though his shirt had caught fire. Almost immediately there was a tremendous bang, and he was thrown to the ground and lost consciousness momentarily. The crash was followed by noise like gunfire. Unfortunately much of the detail has been for ever lost owing to the long time-interval between the event and the many scientific expeditions subsequently made to the area.

This certainly was not the case when one considers the second of these super-fireballs. This was seen in the morning of 12 February 1947. The Sun was shining in a clear sky, when suddenly an extraordinary bright bolide crossed the Eastern Siberian sky, travelling roughly north to south, leaving in its wake a trail of sparks and black smoke. After the passage, loud bangs like cannon fire were heard. These were followed by roars and crashes which echoed round the surrounding hills. Although the fireball appeared at about 10.30 a.m. local time, the trail was visible for the whole of the day. Reports say that the bolide was about half a degree in diameter and took about 4-5 seconds to pass over the sky before exploding into many pieces roughly 6 kilometres above the Earth's surface. It is estimated that the dust trail reached a height in excess of 40 kilometres. The light from the fireball was very strong, some witnesses saying that it was brighter than the Sun. All objects had momentarily two shadows, one from the Sun and one from the fireball. Scientists were on the scene very quickly, and they have been able to draw up a very detailed account of the event which must rank as one of the outstanding natural events of the last half-century. In contrast with the Tunguska incident, much meteoritic material has been collected, about 23 tons, but it is estimated that another 47 tons remains *in situ*. Many craters were found scattered over an area 2·1 by 1 kilometres.

Although nothing like the two incidents just mentioned, there have been four fireballs of note seen from the British Isles during the last few years. Two have produced meteorites, whilst a third is considered unlikely to have resulted in material reaching the Earth's surface, although this can never be proved because the end point was over the sea. The fourth object was the re-entry of an artificial satellite Cosmos 253 rocket. Atmospheric drag continually modifies the orbit of a satellite until it is so low that a stable orbit is impossible. The object then spirals into the denser regions of the atmosphere, and is heated up by frictional heat in exactly the same way as a natural object. From the point of view of an observer on the ground, a re-entry and a natural fireball produce similar phenomena, although in general the artificial bodies tend to move slower across the sky. Re-entries from roughly circular earth orbits have speeds about 8 kilometres per second, although for high eccentric orbits with a perigee lying in the denser regions of the atmosphere, as is the case of some lunar flights, the speed of entry may be much higher. Natural bodies generally have much higher speeds, the actual speed of entering the atmosphere depending on the angle of approach and whether its orbital motion prior to Earth encounter was in the same sense as that of the Earth's (i.e. direct) or in the opposite direction (i.e. retrograde motion).

The first of these events occurred just as it was getting dark on Christmas Eve, 1965. Extensive cloud prevented any one observer from seeing an overall picture of at least four brilliant fireballs travelling on roughly parallel tracks. It is assumed that the original meteoroid broke into three components early in its flight through the upper atmosphere and these made roughly parallel tracks as they approached the Midlands from the SSW. The central components was seen to break into two objects which passed over the eastern and western outskirts of Coventry, respectively. The former was responsible for the fall of meteorites at Barwell some 24 kilometres beyond Coventry. Because no meteorites were recovered from the other fireballs and because no reports were received of possible falls, it is assumed that these other objects were relatively minor fragments of the main mass. The bolide from the main component was orange-red in colour, appeared about the size of the Moon, and developed a long tail in the later part of its flight. This and the fireball to the east left white dust trails which lasted for several minutes. Whereas the main object just went out, the eastern object exploded into four objects, one piece shooting upwards and the others downwards, and all faded rapidly. The western component of the central bolide developed only a short tail, yellow in colour. Because of the complex nature of the tracks, the sound effects reported varied considerably depending on the position of the observer. Multiple sonic booms were reported from south Warwickshire, whilst single bangs were heard by many in the Coventry area. The fourth object, well to the west of the other three, differed in colour and general behaviour. It was reported bluish-green in colour, and there were no sonic effects.

In April 1969, two large fireballs were seen to pass over southern England. The first, on 3 April, travelled in a direction slightly north of west and disappeared at a height of about 40 kilometres over the outer reaches of the Bristol Channel. The head of the fireball had an apparent size about a third of that of the Moon, and was bluish white in colour, likened by one observer to burning magnesium. It continually shed white sparks throughout its flight. The brightness and length of the tail varied considerably during the flight, generally lengthening as the object journeyed westwards. Towards the end of the track, the sparks were reported red in colour. No dust trail was formed nor were any sonic effects reported. Just before extinction, the tail shortened drastically and the head went a reddish colour. From the evidence available, the white colour, the high speed, the high extinction point and the lack of sonic reports all seem to suggest that this object did not survive its atmospheric passage.

The fireball of 25 April was an entirely different affair. This travelled in an approximately north-westerly direction crossing southern England, Wales, and Northern Ireland. When first seen over the English Channel, it was reported as a rapidly brightening yellow object, developing a yellow tail. The head grew rapidly in size to about that of the Moon and became bluish-green in colour. By the time it was over Wales, the head had a very complex structure, with many individual nuclei, appearing green at its leading edge, changing through yellow to orange red say some 2° behind the leading edge. Red-coloured fragments were seen to be continually falling away. Whilst passing over the Irish Sea, two major fragments were seen to separate from the main mass and then fade. As the main object crossed the Irish coast, the bolide suffered a major disintegration and turned orange. It finally broke up and faded just beyond the north Irish coast. It is interesting to note that two meteorites were found at places approximately 60 kilometres apart, Sprucefield and Bovedy. It is possible that these were the remains of the fragments seen to separate over the Irish Sea. From the analysis of the reports it is thought that if the main mass survived the atmospheric passage it would have landed in the Atlantic Ocean, although there is a possibility of undiscovered fragments lying near to the north coast of Ireland. A very strong sonic boom was heard by many people in Wales, and from many points along the Irish coast as far south as Dublin. In the vicinity of Belfast a series of booms and prolonged rumblings were reported.

As mentioned earlier one of the important differences between natural fireballs and those produced by the re-entry of man-made objects is the speed at which they cross the sky. Whereas a bolide will cross the sky in times varying from a few seconds to up to about half a minute, a re-entry may be visible for periods in excess of a minute. The re-entry of Cosmos 253 rocket, seen on 20 November 1968, was observed from west of the Hebrides, crossing southern Scotland, England, passing just east of London and finally fading just beyond the north coast of France. First reports described the rocket glowing like a distress rocket with a short fiery tail, the whole being surrounded by sparks. As it travelled southwards. it became brighter, white on its leading edge but generally orange-red. The tail, increasing in length with time had a yellowish colour. Break-up of the rocket had started by the time it had reached the Midlands, observers reporting many bright objects travelling in formation, each with its individual tail. In the vicinity of London it is estimated that there were thirty such objects. Many observers reported trails 'electric blue' in colour intermingled with the above and which persisted for a few seconds. During its passage over southern England there was a fairly rapid decline in brilliance. A fragment of the rocket went through a window of a house near Southend, and it is thought likely that other fragments reached the ground over Kent. Sonic booms were heard only in a well-defined area near the mouth of the River Thames.

Generally, a bolide becomes visible at a height of 100-120 kilometres when it begins to experience considerable resistance due to collisions with air molecules. This causes the outer layer of the body to be heated up to temperatures in the region of several thousand degrees. An envelope of incandescent gas develops round the body, and can reach a diameter of several hundred metres. It is this huge gas envelope that is seen as the bolide crosses the sky, because normally the object may be only about half a metre across or even smaller. The intense heat vaporizes the outer shell of the body, and this material is swept away to form the tail and the dust trail which can persist for a long time after the passage of the bolide. The behaviour of an object and the formation of the luminous gas envelope are by no means fully understood, and so it is important to collect as much information as possible on these events.

As far as the events seen from the British Isles are concerned, much information was collected from reports made by the general public. In fact, it is safe to say that without these reports, it would have been impossible to have analysed the events with any reasonable degree of confidence. The importance of the part that can be played by the public is fully appreciated, and the British Astronomical Association has set up an organization to handle reports of such events and to co-operate with the Press and television. The purpose is to reduce to a minimum the time interval between the passage of the fireball, the analysis of the reports and if thought likely, the location of the fall area. It is important to locate and collect meteorites as quickly as possible, because some experiments lose their usefulness if the time interval is too long. If any reader is lucky enough to witness a brilliant fireball, such as those described above, they are invited to send their reports to the author; details are given at the end of the article.

In the United States and Europe there are professional organizations geared to tracking these important objects. Just recently, the quick location of the fall area and the subsequent finding of a meteorite were due to the highly efficient Prairie Network, a network of sixteen stations run by the Smithsonian Astrophysical Observatory and covering the central region of the United States. Each station consists of a sophisticated camera system which automatically photographs any fireball seen in such a way that the shutter mechanism chops the trail 20 times per second. If the fireball is seen from two or more stations, then it is possible to deduce a very accurate track, and so obtain a reasonably well defined fall area. It also enables the investigators to obtain highly reliable values for the orbital parameters of the object prior to entering the atmosphere. Referring to the incident just mentioned, the fireball was seen on 3 January 1970 and from the information collected from the Prairie Network stations, the fall area was calculated and a meteorite found by 9 January. The orbit prior to Earth encounter was calculated from information from the photographs – only the second time this has been achieved for meteorite-producing fireballs.

The first occasion on which this was achieved occured on 7 April 1959, when the Pribram meteorite fell in Czechoslovakia. The associated fireball was photographed from eleven stations using all-sky cameras linked in a network covering central Europe. Co-operation between the various networks and observing stations is an essential feature of the study of these events. The Center for Short Lived Phenomena, set up by the Smithsonian Institution, lists all such incidents and informs workers in this field of study within a few days. As an example, it published on 11 December 1970 preliminary details of a fireball of magnitude −16 seen over Austria, Germany and Czechoslovakia on 24 November. It was photographed by twelve stations of the European All-Sky Camera Network, and from the information orbital elements were derived. The information card gave details of the impact area and said that searches were being organized.

Systematic studies of the behaviour of fireballs have led to some very interesting results. It has been found that brilliant fireballs occur far more frequently than was once thought. In contrast to this, the number of meteorite-producing fireballs is much lower than originally considered to be the case. It is now thought that many of the major fireballs have structures resembling comet debris rather than dense material from which meteorites originate. Obviously much more work needs to be carried out. Some investigations need sophisticated equipment, but there is still important work that can be carried out using accurate reports from amateurs.

Note

Any reader seeing a major fireball is requested to send details of the event to:

Howard Miles
21 Babbacombe Road,
Coventry, CV3 5PE
Tel: Coventry 411655

It is impossible to make a note of all relevant facts, but the following gives a guide to the information that may provide useful data for those who are analysing the reports.

Name; Address; Date; Time;

General direction of travel of fireball;

If the fireball passed more or less overhead, when facing the direction from where it came, on which side did it pass, right-hand side or left-hand side?

If it did not pass overhead, in which direction was it highest in the sky?

In what direction did extinction occur?

Were sonic effects heard and if so, estimate the time interval between the passage of the fireball and the arrival of the first sounds.

Description of the fireball and sudden changes in its appearance, the tail and any dust trail.

The Far Side of the Moon

C. A. CROSS

Observing from the surface of the Earth imposes a restriction of position which is uniquely important with respect to the Moon, since an Earth-based observer can never see the averted hemisphere, and can only view tangentially those areas which are exposed by the optical libration at the limb. Even the observation of the visible hemisphere is hampered by the turbulence in the atmosphere, which means that the 'seeing' is always less than perfect. Although amateur and professional astronomers are all painfully aware of these restrictions, few of them realized that the earliest outcome of successful space-flight would be to sweep the restrictions aside, by providing unmanned space probes which could observe from points distant from the Earth, and outside the veiling effect of the atmosphere.

Those of us who had made these deductions were, however, sadly disappointed when the first Soviet Luna 3 pictures of the Moon's far side were published in 1959. The positional limitation had been overcome, but the quality of the pictures was abysmally low. For the next six years our knowledge of the far side was to remain roughly equivalent to the naked-eye view of the familiar hemisphere at full moon. This was only enough to establish the absence of any extensive dark seas. The reason for the poor performance lay primarily in the choice of full moon illumination, so that even with high resolution the pictures could not have shown the sort of topographic detail which is visible near the terminator. Even so, details of rays and bright rings were not visible, and the pictures were probably both over-exposed and degraded during transmission back to Earth.

The long-awaited improvement in resolving power came in 1964 and 1965, when the American Rangers 7, 8, and 9 transmitted close-up pictures as they fell to destruction in the Mare Nubium, Mare Tranquillitatis, and on the floor of Alphonsus. These pictures, all of Mare-type areas on the visible face, gave up to a thousandfold improvement over the best Earth-based pictures. The magnitude of this achievement would perhaps have been more widely appreciated if the Rangers had revealed a new or startlingly different lunar topography. What they showed was that the familiar topography of the average 10-km square of Mare, containing one or two large craters, and increasing numbers of smaller craters, is repeated at proportionately smaller scales for a 1-km square, for a 100-metre square, and even for a 10-metre square.

The Russians made the next advance in 1965, when their Zond 3 vehicle obtained high resolution pictures of the Western portion of the averted hemisphere. The Soviet results were combined with those obtained by the American Orbiters 2, 3, and 4 to give the first really good view of the far-side topography for the 1967 International Astronomical Union meeting in Prague. These results convinced most astronomers that space probes were worth while, and started the work of I.A.U. Commission 17 on naming the principal far-side craters.

Although the recent Apollo flights have produced some spectacular colour photographs in the equatorial belt, they have not improved significantly on the Orbiter pictures. These cover over 99 per cent of the whole surface of the Moon, with a resolving power which is always ten or more times better than the best Earth-based pictures.

The provision of high-resolution photographs is only the first stage in the development of a satisfactory map. The position is analogous to the construction of a terrestrial map from aerial photographs, but is much more difficult for the Moon, because there are not yet any firmly established ground survey points to which the photographs may be related. Moreover, the Orbiter pictures do not preserve their dimensional accuracy through the chain of scanning, transmission, and reconstruction on the Earth. In spite of these difficulties a number of maps have been

Table 1: Charts and Globes showing the Lunar Farside

Item	*Scale*	*Size*	*Projection*	*Supplier*	*Price*
A.C.I.C. LMP2 and 3	1:5,000,000	40″×29″	Mercator	U.S. Government Printing Office, Washington D.C. 20402	50 cents each
A.C.I.C. LPC 1 Farside names overprinted	1:10,000,000	38″×26″	Mercator and Polar stereo	U.S. Government Printing Office, Washington D.C. 20402	50 cents
Farside Chart, with name key	1:12,000,000	21″×24″	Lambert Azimuthal	C. A. Cross, 225 London Road, Northwich, Cheshire	£0·375
The Earth's Moon (Farside and Nearside)	1:11,620,000	42″×28″	Lambert Azimuthal	National Geographic Society, 11 Stanhope Gate, London W.1	£0·84 on paper £1·25 on plastic
Map of the Farside by Antonin Rukl	1:10,000,000	21″×24″	Lambert Azimuthal	Reidel Publishing Co, PO Box 17, Dordrecht, Holland	Not known
Scan Lunar Globe	1:22,000,000	6″ diameter	—	George Phillip and Sons, Victoria Road, London N.W.11	£1·25
Maruzen Lunar Globe	1:11,000,000	12″ diameter	—	Stern Ltd, Alliance House, 877 Finchley Rd., London N.W.11	£5·975
Rand McNally Lunar Globe	1:11,000,000	12″ diameter	—	Campus Classics, 95 Marison Ave, New York 10016	$12·95
Rand McNally Lunar Globe	1:1,830,000	72″ diameter	—	Rand McNally & Co, P.O. Box 109, Ossining, New York 10562	$7,600
Armorex Lunar Globe	1:11,000,000	12″ diameter	—	Armorex Ltd.. P.O. Box 9, Bishop's Stortford, Herts	£5·50
Armorex Lunar Globe	1:5,500,000	24″ diameter	—	Armorex Ltd., P.O. Box 9, Bishop's Stortford, Herts	£77·50
Rico Illuminated Globe	1:16,500,000	8″ diameter	—	Edward Stanford Ltd., 12–14 Long Acre, London W.C.2	£3·475
Rico Illuminated Globe	1:13,200,000	10″ diameter	—	Edward Stanford Ltd., 12–14 Long Acre, London W.C.2	£4·475

developed from the N.A.S.A. Orbiter data, and Table 1 gives details including price and availability where known.

The two Aeronautical Chart and Information Centre (A.C.I.C.) maps represent the basic information, derived directly from the original Orbiter data with a positional accuracy of between 10 and 15 km. The smaller LPC map has been re-issued, overprinted with the new far-side nomenclature, and this and the author's chart are the only two which as yet provide the new names. All these charts, except that from the National Geographic Society, rely upon the A.C.I.C. positional data. The latter have, however, derived their positional information quite independently, and the February 1969 issue of the *National Geographic Magazine* gives an interesting account of their method. A plain globe, marked out with lines of latitude and longitude, was photographed from positions corresponding exactly to those occupied by the Orbiter vehicle when it took the lunar pictures. The grids generated were then superimposed on the Orbiter photos to give the positions of the features shown.

Any map involves the distortion of features on a spherical surface so as to fit them on a plane surface. The only way to avoid this distortion is to reproduce the features upon a globe. Even before the lunar probes showed us the averted face, several globes of the Moon were constructed. Sir Christopher Wren built one for Charles II. All these globes necessarily showed a blank hemisphere, but now a complete globe can be constructed for the first time. The available globes are also listed in Table 1. There has been a minor boom in their production to meet the interest generated by the Apollo landings. Even the simplest and cheapest Scan 6″ globe is a most useful ancillary to any chart to clarify the way in which the features really fit together. In the more expensive ranges the Armorex and Rand McNally globes can be recommended as accurate portrayals of the topography. The McNally 72″ globe has the surface sculptured in six times exaggerated vertical relief, matching their Geophysical relief globe of the Earth. It is intended for display purposes in planetaria, universities, etc., and with proper illumination it will simulate the changing shadows of the terminator over the whole lunar day.

At the I.A.U. Meeting at Brighton in August 1970 the working group of Commission 17, which had started its task in 1967, gave its report recommending names for 513 far-side features. Added to the existing 21 names this gave a total of 534: 504 of these names commemorate famous men of science, engineers, and inventors. Some of them (Omar Khayyám, Chaucer) are perhaps more familiar for their endeavours in other fields, but we may assume that they won their place upon the Moon because of their astronomical work. Of the remaining 30 names, 3 are seas (Moscoviense, Ingenii, and Orientale), 3 are figures from Greek mythology (Apollo, Dædalus, and Icarus), and 18 are evenly divided between astronauts and cosmonauts. There are also 5 writers and 1 publisher of science fiction (Cyrano de Bergerac, Danté, Verne, Wells, Ley, and Gernsback). The report of the execution of this monumental task quite stole the limelight at the Brighton conference, and it is a tribute to the fair and sensible way in which the names were chosen, in consultation with the National Academies of Science of all the countries of the world, that the proposals have been ratified with hardly any changes.

At first glance at any of the maps or globes listed in Table 1 one is overwhelmed by the profusion of randomly distributed craters. They range from gigantic rings, far larger than any on the visible face, down to countless myriads of smaller craters. It is clear from fig. 1 that the Mare Orientale is by far the largest of these circular features. When seen from vertically above the Western limb it dominates the whole hemisphere like a gigantic bullseye. The Rook and Cordillera mountains form two complete rings 600 km. and 900 km. in diameter. They are surrounded by a zone a further 400 km. wide which is mantled with a blanket of ejected material, and scored with near-radial grooves and chains of secondary craters. There is a third lower and incomplete ring of hills on the central floor, and this and the annulus between the Rook and Cordilleras is partially

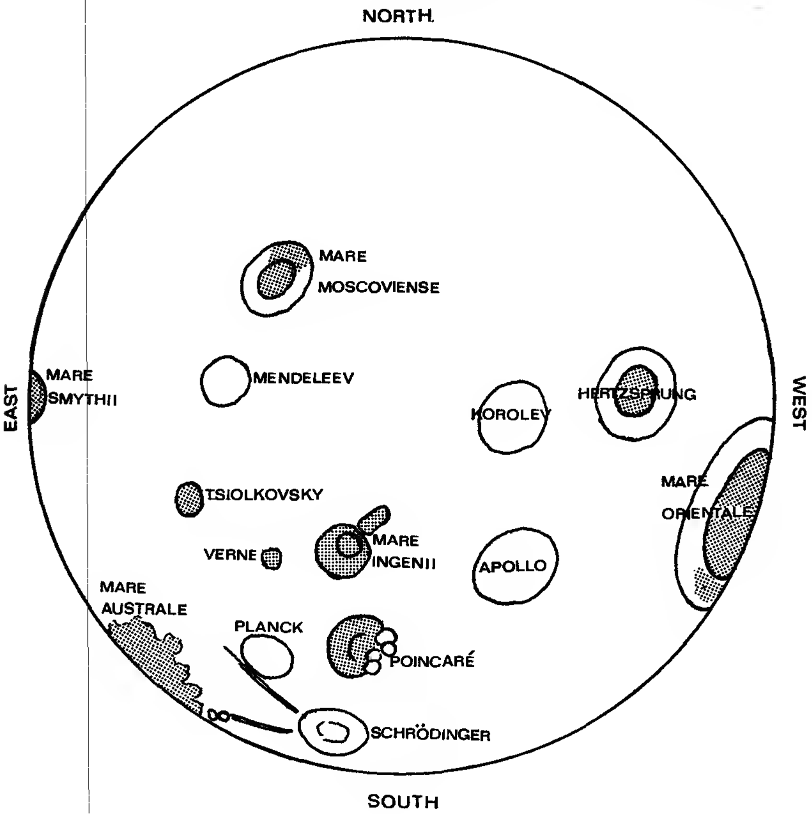


Fig. 1

flooded with Mare material. The very limited amount of the Mare material is clearly shown by the numerous protrusions, which are unsubmerged parts of the original floor.

The next largest ring, Hertzsprung, although fully 500 km. in diameter, is much less conspicuous. It lies 1,400 km. north-west of Orientale, and again shows a double-ring form. It must, however, be considerably older, since it is peppered with large and small craters, whilst Orientale has very few. At least three crater chains and associated lineaments from Orientale lie across it.

The third largest formation is Mare Moscoviense, which has an outer ring 500 km. and an inner ring 350 km. in diameter. All of the nine Russian cosmonauts except Gagarin have been assigned small craters in and around this sea. Tereshkova is the most northerly of the chain of four craters within the Mare, and is the only crater on the Moon named after a living woman. As befits the first man in space, Gagarin is commemorated by a 250 km. diameter crater which is the eastward neighbour of Tsiolkovsky. The central areas of both Hertzsprung and Moscoviense are partly filled with dark Mare material, and this darkness ensured that Mare Moscoviense was seen on the first Luna 3 pictures, becoming with Tsiolkovsky the first-named far-side feature.

Two other formations are large enough to be classed as Maria, although they have light-coloured floors. They are Apollo and Korolev, 500 km. and 400 km. in diameter, respectively. Apollo is more heavily cratered, and presumably the older of the two. Six of its craters have appropriately enough, been named after six of the Apollo astronauts. The members of the Apollo 11 team have, however, been assigned small craters near where they landed in the Mare Tranquillitatis.

Poincaré is an even older ring-plain, which has virtually the whole of its eastern half obliterated by six or seven overlapping craters, each one some 100 km. in diameter. The original diameter of Poincaré itself was probably 400 km., and it may well once have had an inner mountain ring of which only fragments of the western half survive.

So far I have described briefly the six largest far-side ring formations, which are all over 300 km. in diameter. There are a further 17 craters between 200 and 300 km. in diameter, and a further 91 between 100 and 200 km. These numbers correspond closely with what would be expected if the lunar highlands were to occupy the whole of the visible face, and indeed the simplest description of the far hemisphere is that it is entirely highlands.

Amongst the smaller craters we may single out the following for special mention:

Schrödinger, near the South Pole, because of its two remarkable radial grooves. The longer, Rima Planck, extends some 350 km. in a northerly direction. Deeper, and slightly shorter, Rima Schrödinger extends NNW. to end in a pair of craters, Moulton and Chamberlin. The rims of this groove are raised above the surrounding terrain, indicating that it is not a simple subsidence feature.

Tsiolkovsky, because of the exceptionally dark Mare material upon its floor. A central peak stands up in it like an island. A blanket of ejected material covers two-thirds of the floor of its larger western neighbour, Fermi, whose eastern wall has been destroyed by Tsiolkovsky. Ejecta and secondary crater chains also dominate the ground south of Tsiolkovsky, covering Neujmin and Waterman.

Mare Ingenii, because of the associated peculiar elongated crater Van der Graffe, which extends from it in a north-easterly direction. This seems, like Schiller on the front face, to be made up of two craters fused into one.

With the topography of the far side described in broad outline, it is proper to enquire what light is cast upon the theories of its origin. If we consider the largest craters on the far side, they are much bigger than any of the near-side craters. In fact, if we compare fig. 1 with fig. 2, we see that they are similar in size to the circular maria. A careful analysis of these very large circular formations suggests that they are distributed in an essentially random fashion over the whole surface of the Moon. The distribution of Mare material is, however, very far from random. Much more of it has been produced on the visible face, and it has filled the five largest rings on this side (Imbrium, Serenitatis, Crisium, Nectaris, and Humorum), as well as many of the irregular spaces between them (Porcellarum, Frigoris, Nubium, Tranquillitatis, and Fæcunditatis).

Because of the absence of this filling we can see the double-ring form clearly displayed in four out of the six largest far-

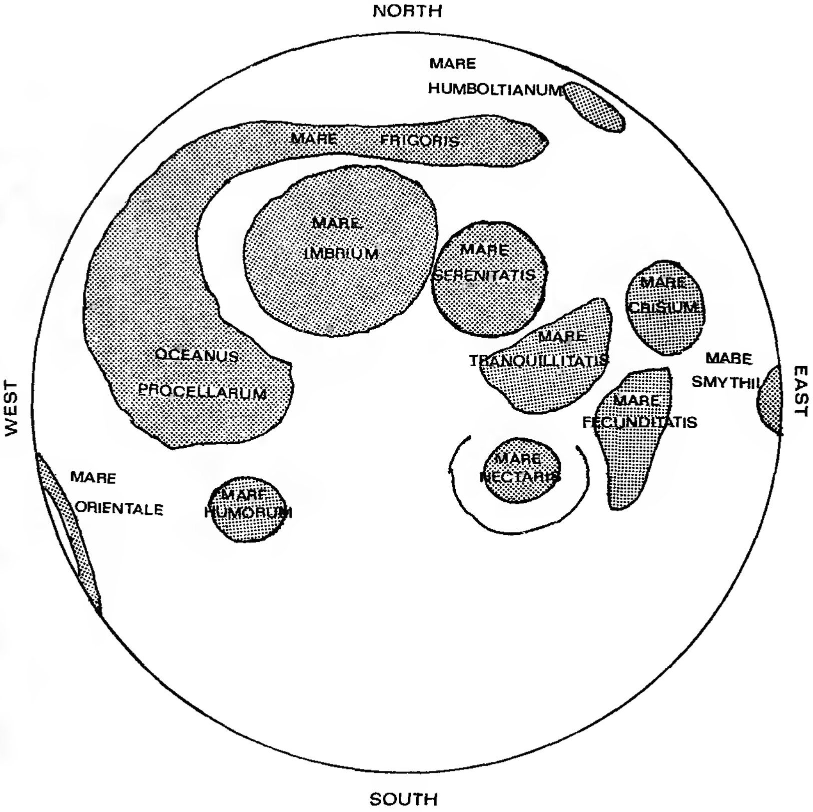


Fig. 2

side rings, whilst it is only clearly visible in Mare Nectaris on the near side. Long before the far-side pictures were available R. B. Baldwin had predicted that the double-ring form would be characteristic of the very large impact features. Its discovery on the averted face lends impressive support to his hypothesis.

If we accept the randomness of the large ring features, we are left with the question of why the Mare material is mainly on the near side. Both Apollo 11 and 12 landed on Mare material, and the samples returned were all igneous rocks. About one third of the material was massive crystalline rock (ilmenite basalts from Tranquillitatis, and basalts and granites from Procellarum). The remaining two-thirds was rather poorly consolidated brecchias consisting of very diverse rock fragments in glassy matrices. These results suggest that the Mare are extensive ancient lava flows, whose upper surfaces have been fragmented and mixed by repeated meteorite impact so as to form a regolith or lunar soil, which is believed to be between 5 and 15 metres deep.

Most lunar observers will feel that this is a plausible sequence of events, since when observed telescopically the Maria certainly look as though they were emplaced as liquid. The wrinkle ridges look like 'tide marks', and in some places definite lobate flow boundaries can be seen. It has now been shown experimentally that the Apollo 11 rocks melt at about 1,200°C to give an exceptionally fluid lava, which should flow and spread very easily. Such fluid lavas do give rise to extensive lava plains on the Earth, where they are not generally associated with explosive vulcanism.

Strontium/rubidium radioactive dating places the lava flooding of both Serenitatis and Procellarum between 3·5 and 3·8 thousand million years ago (the oldest rocks known on the Earth are about $3{\cdot}4 \times 10^9$ years old). Dating of the fine material from both lunar sites gives $4{\cdot}6 \times 10^9$ years, and it is tempting to speculate that this arises because the dust is mixed with materials thrown as rays from the supposedly older highland areas. If this is so, then the lunar highlands may well preserve the original surface of the Moon which was generated during its formation, for the oldest meteorites give similar dates, and the Solar System itself is not thought to be much older than this.

At this very early epoch the Moon was very much closer to the Earth than it is now. Thus the anorthosite crust may have formed as a much thicker layer on the far side than the near side. Similarly, when magmas did form in the basaltic mantle, the amount would be depleted on the far side and reinforced on the near side. On this basis there is an interval of about 10^9 years between the formation of the really large-scale topography during the final stages of the Moon's accretion, and the flooding of the near side with lava. This substantial interval accounts for the numbers of quite large subsidiary craters, such as Archimedes and Sinus Iridum in the Mare Nubium, and Fracastorius in the Mare Nectaris, which have obviously been formed within the boundaries of the circular Mare, and shared in the inundation when it eventually came.

On this basis, the actual flooding with lava must be regarded as the cause of the gravity anomalies, or 'mascons'. Whilst the Earth's mantle is believed to have continued to behave as a plastic convective medium, carrying the continents upon it as drifting tectonic plates, this period is regarded as being very short in the Moon's history, so that the primitive single continental area analogous to Earth's panagea was not disrupted by continental drift, and the gravity anomalies of the mascons were not cancelled out by isostatic adjustment.

There are, however, many puzzling features which are not fully explained by the theories outlined above, and it is important to realize that no wholly consistent theories can be put forward with our present very limited knowledge. The situation will improve as further samples are obtained, and the next really big step will be to obtain samples of the highland material for analysis and dating.

We have seen the start of exploration of the visible face, and may naturally ask when this will be extended to the averted face. This will depend primarily on whether it is thought worth while to continue investigation of the Moon at all. There is a clear indication that, despite the immensely important and exciting scientific results which have come out of the Apollo flights, America is not prepared to maintain them. Most scientists will agree that the immense amount of publicity about the Apollo flights has been directed towards ephemeral features, such as the personalities of the individual astronauts, and the dangers which they face from mechanical failures. If there is, as

I believe, a widespread feeling that the flights have not been really worth while, then all those same scientists cannot escape some responsibility for failing to explain just what has been gained.

In this climate of opinion we see that future manned exploration will depend very much on making it a much more economical process, by the development of re-usable vehicles. Alternatively, unmanned exploration may be conducted by the kind of vehicles demonstrated by the Russians (Lunokhod I, etc). Whatever method is adopted, the problem to be overcome in exploring the far side is the maintenance of communication. The use of an orbiting command module as a radio relay would only provide intermittent contact. A possible solution lies in the use of radio relays sited at the Lagrangian equilibrium points. Relays at the Trojan points, 60° ahead or behind the Moon in its orbit, would provide full cover for landings anywhere except between 150°E and 150°W. It also seems possible that a relay could be sited beyond the Moon, just to one side of the further Lagrangian point, when it would provide cover for the whole far side. With communication assured, it is no more difficult to land anywhere on the far side than anywhere on the near side. If, however, present suspicions are confirmed that the Moon's surface is essentially uniform and geologically undifferentiated, then there will be no reason to explore the far-side surface in search of mineral deposits which would be of use on the Moon. In this event the reason for venturing into the far-side regions might turn out to be precisely because they are so difficult to communicate with. The far-side region is the only place in the Solar System which is permanently shielded from radio transmissions from the Earth. Because of this it might prove to be the best place in the Solar System for a radio telescope.

An Unusual Solar Cycle

W. M. BAXTER

There is a well-known cycle of activity of the Sun. It is referred to as the 11-year cycle, and is evident from the number of sunspots that occur, quite apart from the variations in the various forms of radiation received by us. During the sunspot 'maximum' period there are always numbers of spots visible whenever a telescope is turned on the Sun, whereas during the 'minimum' period many days and weeks go by without a spot being visible. Actually the period between one maximum and the next can vary quite considerably – from about 9 to 14 years – the average being 11.1 years. The rise from minimum to maximum is usually more rapid than the decline that follows, the rise taking about 4.5 years and the decline 6.5 years.

Another phenomenon depending on the cycle is the latitude of the sunspots. They are never seen at the poles of the Sun, and are infrequent on the equator. The zones of most activity are in bands approximately 15° North and South of the equator, but when spots first appear after minimum they occur as few in number and small in size in the higher latitudes – at about 40° both N and S. Then, as the cycle proceeds, the spots increase in numbers and larger ones appear from time to time, but all at somewhat lower latitudes. This 'drift' continues until, at maximum, the latitudes average about 15° as mentioned, but even lower latitudes are reached as the activity declines until the spots fade out near the equator. In the meantime the new cycle high-latitude spots have begun to appear so that there is an overlapping of the cycles.

Sunspot counting, as a measure of solar activity, is not an 'exact science'. The generally accepted method is that adopted by Zürich, started there by R. Wolf in 1848 and continued since, currently by M. Waldmeier. This involves a formula that takes into account a factor which depends on the ability and equipment of the individual observers. The figures derived from other sources, e.g. Boulder (U.S.A.), Fraunhofer Institut (Germany), etc. do differ, and the British Astronomical Association Solar Section adopted many years ago a simplified form of counting 'Active Areas'. The point to stress is that if the results are plotted for different methods, using different but appropriate scales, the curves of activity follow the same general shape with its ups and downs.

In the year 1957 (December) there was an exceptionally high maximum, in fact an all-time record, and it was fortunate that this coincided with the International Geophysical Year (I.G.Y.) when scientists of many nations gathered in the Antarctic regions to study the radiations from the Sun during maximum activity and, in particular, the electrified particles that curve towards the magnetic poles of the Earth and cause the wonderful polar lights – the auroræ. (The Arctic regions, being largely floating ice, are obviously not suitable for such stations.) The I.G.Y. was followed by the I.Q.S.Y. (International Year of the Quiet Sun) when the scientists could make comparisons with the lowest activity which actually occurred in 1964. Since then the stations have continued their work, which is a fine example of how the major nations can collaborate when the will is there.

As for the present cycle, fig. 1 shows the curve of activity derived from the joint observations of the members of the B.A.A. Solar Section – going back to 1956 to include the last part of the rise to the 1957 maximum and showing the normal drop to the 1964 minimum. As the maximum occurred right at the end of 1957 the drop in 1958 was slight and one can see that the drop to 1964 took about the normal six and a half years with a normal rise following to a modest maximum in 1968. What makes the present cycle unusual is the indefinite date of this maximum. The activity was certainly much lower than the activity recorded in 1957 but whereas (at the time of writing)

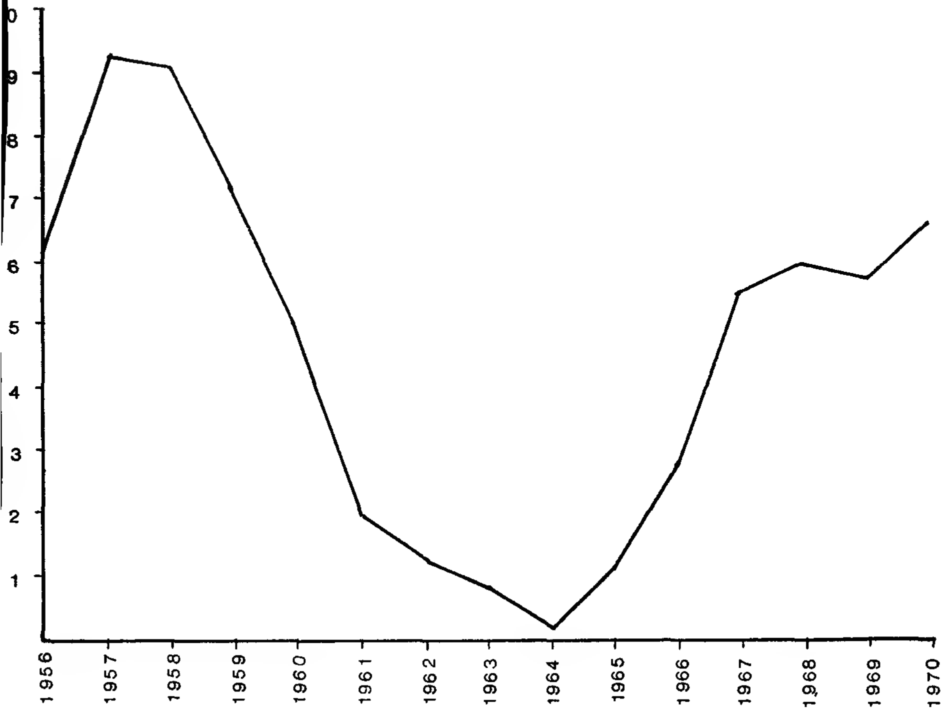


Fig. 1

Waldmeier using a method of 'smoothing' has announced the date of maximum as the end of 1968, the slight 1969 drop has been followed by an appreciable rise in 1970 – according to the figures averaged from reports of a considerable number of B.A.A. Solar Section observers. In fact, peaks were recorded in December 1969 and in February, May, July, and September 1970. When B.A.A. figures are 'smoothed' by taking the averages of five rotations of the Sun, the highest peak would appear to have been about April/May 1970.

Another strange feature of this cycle is the wide range of spot latitudes that have been observed. Normally the spots should have been in the lower latitudes, and higher-latitude spots would not be expected until the approach of the next minimum. During 1970 some relatively high-latitude spots (30° and higher) were recorded on several occasions while one observer reported a small transient spot at 40°N, while another saw one at 49°S, both in July and such latitudes would be very exceptional at any time.

It may be that we shall later have a definite date for the most recent solar maximum, but the sunspot counts, together with the exceptional range of spot latitudes, do indicate an unusual cycle, with perhaps two maximum peaks of activity, one at the end of 1968 and the other early in 1970.

Modern Infrared Astronomy

M. COHEN

Introduction

Thousands of years ago the first 'astronomers' raised their eyes to the starry skies and noted the colours, groupings, and movements of the numerous points of light that greeted their gaze. Although the astronomers of later centuries have possessed large and complicated telescopes, they have been restricted fundamentally to using their eyes, or eventually the photographic plate, as the ultimate detector of celestial objects. It is only in the most recent decades of astronomy that this restriction has been reduced. We are able now to discuss the electromagnetic spectrum of astronomical objects with more authority than ever before, for we have opened up vast, new, and exciting fields which make possible unified theories, based upon a far broader range of astrophysical knowledge than merely visible information. The discoveries of radio-astronomy are well known, in the fields of galactic structure and extragalactic sources; rockets and satellites have been carrying sensors to detect X-rays and ultraviolet radiations in the past few years. And in this article I should like to introduce some of the discoveries made by infrared astronomy, dwelling upon the observational results rather than the techniques involved or the historical background to this science.

A glance at fig. 1 will indicate the rough extent of the infrared (IR) region of the spectrum. One may regard the redward end of the photographic plate's grasp as the beginning and the short-wave end of the so-called microwave region as the extreme limit of the infrared. It should, however, be recognized that in fact such limits are diffuse, especially in the case of the far-infrared

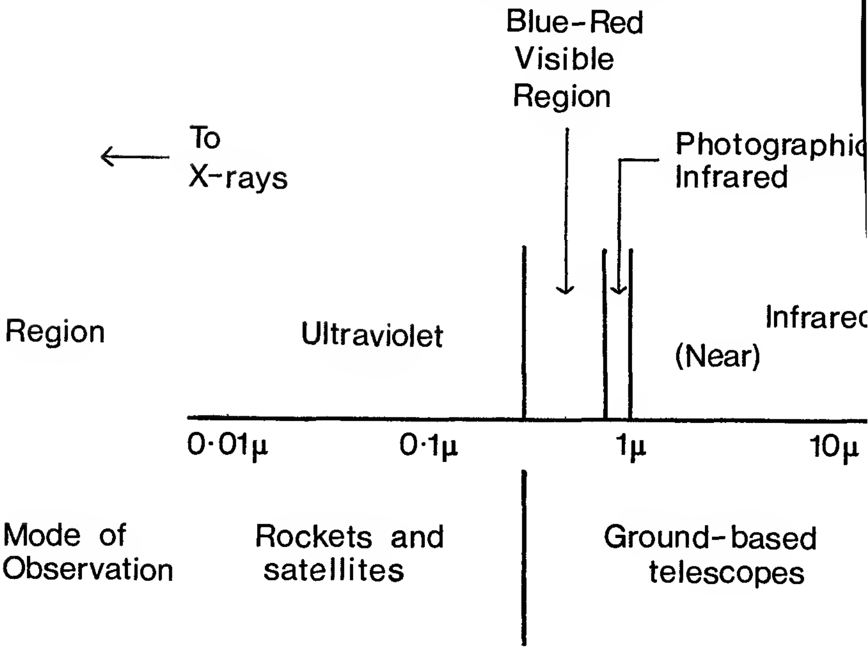
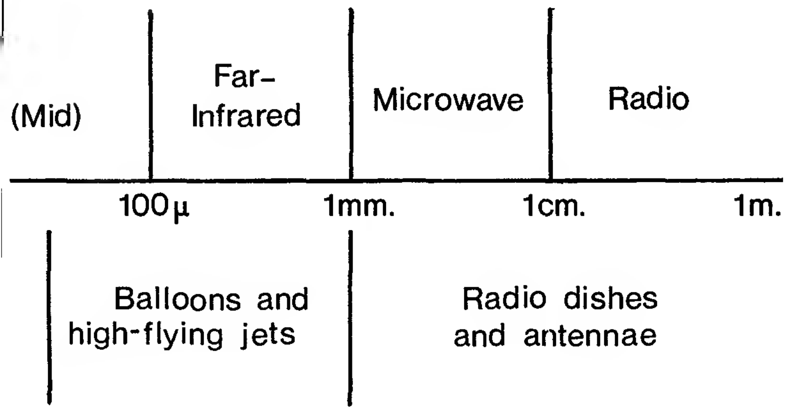
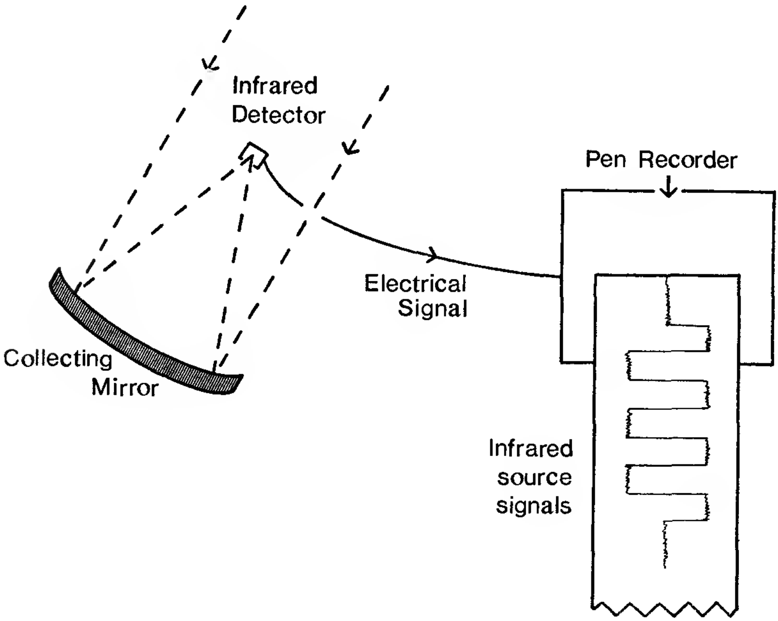


Fig. 1

which merges imperceptibly into microwave astronomy. Numerically, the IR extends from approximately 1 micron to 1 millimetre (a 'micron' is one-millionth of a metre) and may be considered as a 'missing link' between visual and radio-astronomy. In order to acquire a feeling for the subject, let us consider the general problems confronting any astronomer, namely that of 'seeing' an object outside the Earth's environment, and then look at the specific difficulties encountered in the IR. Radiation from space must overcome three main obstacles before it may be analysed; it must traverse our atmosphere, it must be collected by a mirror, dish, or lens, and, finally, all the information acquired by the collector must be detected, for example by chemical or electronic means.



The atmosphere is a most severe problem in the IR, for gases such as water vapour, carbon dioxide, and ozone will greedily absorb their shares of the incoming radiation and consequently may be likened to filters. This has prompted some IR astronomers to fly their telescopes in balloons or high altitude jets in order to minimize the effects of such gases. Nevertheless, most work is done from the ground and, by being selective, the IR astronomer may acquire much information. He has to observe within certain 'windows' in the infrared (defined by gaseous absorptions) usually from dry sites to lessen the effects of water vapour. This is as if one were obliged to observe only the red, yellow, and blue colours of the visible spectrum because the atmosphere absorbed orange, green, indigo, and violet. Fortunately, man suffers no such curtailment of vision, and it is only when seeking data outside the everyday colours that ground-based astronomers must be prepared to use particular wavelengths as opposed to all of a spectral region. Some IR waves are absorbed on passing through glass, and thus an IR telescope employs a mirror instead of a lens as its collecting agent. The third major problem is that of detecting the rays, for neither the human eye nor the photographic emulsion is capable of recording infrared waves, and it has taken a combination of semi-conductor, electronic, and low-temperature techniques to



1 micron = 1/1,000,000 metre
= 1/1,000 millimetre
= 10,000 Ångström units

Fig. 2

evolve a working detector system. To describe comprehensively the details of current and projected devices sensitive to the IR would require many pages of this book, and also draw upon technical knowledge possessed by few readers. We shall choose, therefore, to think of an infrared telescope in terms very similar to those of radio-astronomy: it comprises a collecting dish (mirror) and a receiver (detector), and once the radiations are converted by the detector into electronic signals they may be amplified and subsequently displayed as a series of numbers and/or as a chart record made by a moving pen. These records are the raw material of observational infrared astronomy.

We shall need one further important idea before discussing results. Suppose that, in the laboratory, a black cube of metal is heated to different temperatures and the resulting 'colour' of the metal is examined (think of white-hot steel and red-hot pokers). We should discover a relation between the curve showing which radiations are coming from the metal and with which intensities, and the temperature (fig. 3). The shape of this

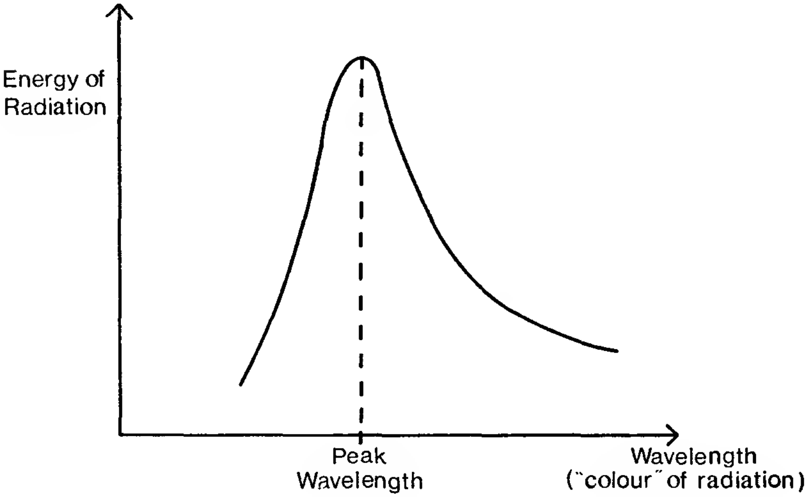


Fig. 3

curve is characteristic of the energy emitted from a hot body and it is called the 'black-body curve' at the given temperature (we used a black cube in order to reflect as little and absorb as much of the applied heat as possible – hence the term 'black-body'). The wavelength at the peak of such a curve is related to the temperature by the formula

[(*peak wavelength*) × (*temperature*) = 3000 (*approximately*)]

where we measure wavelengths in microns and temperatures in degrees Kelvin (°K); 0°K is −273·15° Centigrade. This curve explains what we mean by saying that the Sun appears yellow, for its black-body temperature of radiation is about 5,800°K corresponding to a peak wavelength of about 0·5 microns, in the yellow wavelength region. Note that we do not mean that *all* the radiation appears yellow; the Sun emits radiations of all wavelengths, and our difficulty lies in explaining the processes involved only if the amounts of radiation observed are other than we would expect from a simple black-body curve. For example, we shall see later that many stars which appear to be black-body radiators throughout the visible spectrum do not follow this same curve in the infrared. The table lists peak wavelengths and corresponding temperatures for several stars, and we see that if a star radiates its peak of energy in the IR then it is indeed a very cool star by comparison with ordinary visible stars. Here is a fundamental idea in IR astronomy – celestially cool objects are prominent in the infrared.

TABLE 1. PEAK WAVELENGTHS

Object	*Approximate Surface Temperature* (°K)	*Peak Wavelength of Black-body Curve (microns)*	*Spectral Region of Peak Wavelength*
Vega	10,000	0·3	Ultraviolet
Sun	5,800	0·5	Visible: yellow-green
Aldebaran	3,600	0·8	Near infrared
Typical IR star	1,500	2	Near infrared
Circumstellar Dust Cloud	600	5	Near infrared
Cool Gas Cloud	30	100	Far infrared
Microwave Background	3	1000 = 1 mm	Microwave radio

The Solar System

Within the Solar System, numbers of fascinating problems have been uncovered by infrared astronomy. Scans of the lunar surface have revealed a variety of 'hot spots' and also some 'cold spots' – areas where the temperature is raised or depressed relative to the local average. Some hot spots coincide with bright-rayed craters such as Copernicus and Tycho and, since these are large features, small-scale resolution can be employed successfully. Furthermore, the high-resolution photographs provided by the Lunar Orbiter spacecraft permit a detailed analysis of the lunar surface in the regions which exhibit thermal anomalies. Thus it has been established that very many of these anomalies, both large and small, strong and weak alike, correlate with boulder fields on crater floors and elsewhere. The interpretation of the IR data is that a critical size of boulder block exists, such that the heat absorbed during the lunar day is well retained and the boulder radiates this energy over and above its surroundings during the long night, or in eclipse conditions. Indeed, much mapping of thermal anomalies has been carried out during lunar eclipses, and more than a thousand of these areas are now known. Not all need be boulder-strewn regions, for local areas where the surface composition varies significantly, compared with the lunar average, regarding thermal properties, also would show up in the infrared. However, the rock hypothesis is a strikingly attractive one.

Infrared spectroscopy is a highly developed science, and there exist a number of complex techniques, both mathematical and instrumental, enabling very fine wavelength resolution to be obtained. Molecules in a planet's atmosphere leave 'fingerprints' in the form of dark absorption bands, especially in the infrared region of a spectrum and, provided that the effects of gases in the Earth's atmosphere can be recognized and subtracted, the IR spectrum of a planet contains vital information concerning the composition and pressure of an atmosphere. For Mercury, upper limits have been set on the abundances of carbon dioxide and molecular oxygen and hydrogen, but the broadness of a particular IR absorption feature was interpreted, several years ago, as implying the existence of an atmosphere whose surface pressure exceeded 3 millibars. (Typical terrestrial values are around 1000 mb as sea-level.)

Venus possesses a considerable atmosphere, predominantly of carbon dioxide, and here we may comprehend the power of the IR studies. It has been possible to detect and measure slight traces of carbon monoxide, hydrogen chloride, and hydrogen fluoride with abundances, compared with carbon dioxide, of 45 parts per million, 6 parts per ten million and 5 parts per thousand million, respectively. The surface pressure of the Martian atmosphere is deduced to be from 5 to 15 mb from measures of strong near-infrared carbon dioxide bands, and carbon monoxide has also been detected. Jupiter shows deep absorptions of methane largely, with molecular hydrogen, solid ammonia, and possibly ice. The most interesting feature of Saturn's spectrum relates to the composition of the particles in the rings, which in 1966 it was speculated were covered with paraformaldehyde, while methane was also seen. Thus infrared is a powerful tool for the astronomical chemist and the theoretical speculator!

Other ways in which infrared astronomy has contributed new knowledge can also be found in a discussion of the planets. During transits of the shadows of Ganymede and Europa, Jupiter's satellites III and II, across the Jovian disk, the infrared flux received in the 8–14 micron region was seen to increase some thirty times, during observations made in 1965 with the 200-inch Hale reflector. This decayed to a normal value after some fifteen minutes, and an explanation in terms of the gaseous atmosphere of Jupiter locally readjusting to the eclipse conditions, involving convection of the deeper and warmer layers could be correct. To my knowledge, however, this effect has not been observed again. Despite its name, Jupiter's Great Red Spot shows no correlation with infrared features, and it is the dark north-equatorial belt and a dark spot adjoining a white ovoid in the south temperate zone which displayed the greatest localized IR radiation.

Even more intriguing is the discovery, based upon IR observations in the region 5–25 microns, that Jupiter and Saturn are radiating more total energy than they receive from the Sun. This implies the existence of internal energy sources and the most popular explanation is a gradual and continued gravitational contraction. The shrinkage required to explain these excesses of radiation (a factor of 3 for Jupiter and 2 for Saturn) is at most of the order of a few millimetres each year, and the energy is furnished by the loss of gravitational potential energy. As it was expressed in 1965, one could regard Jupiter as a star that possessed too little mass to collapse on to itself sufficiently to turn on the nuclear processes which cause stars to shine. Conceptually, this may seem an extreme interpretation, but we shall meet this same idea of converting gravitational energy into radiant energy again when discussing the formation of stars. We shall return to the Solar System very briefly with mention of a comet later, but now it is time to move outwards in our Galaxy, to focus our attention upon stars rather than planets in quest of infrared sources.

Star Formation

One area of infrared astronomy in which I am particularly interested relates to the processes of star formation. A star begins life as a large and diffused cloud of atoms and gas molecules (mainly of hydrogen) together with grains of dust. If a sufficient mass of this cloud is gathered together it may become 'gravitationally unstable to collapse'; that is, if it begins to contract then it cannot stop, due to the mutual gravitational pulls of one part of the cloud upon another. The inside of the cloud shrinks on to itself becoming hotter and more dense at the centre, and the 'core' that will eventually become a star is formed (fig. 4).

Now, let us consider the conversion of energy in the collapse process. If we liken the original cloud to a blown-up balloon,

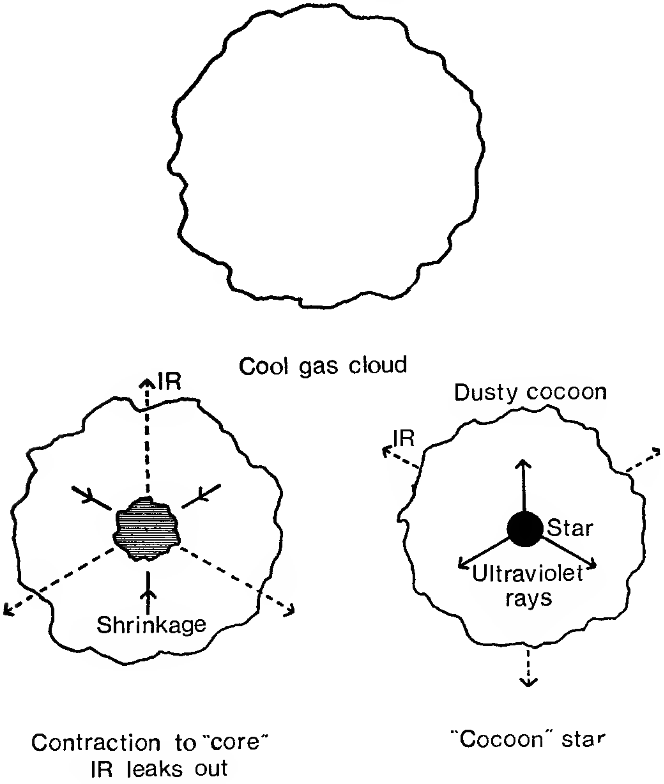


Fig. 4

then collapse occurs if we allow air to escape from the balloon; this escaping air is indicative of energy leaking from the system – the energy that we put into the balloon to blow it up to the initial extended state. By analogy, if our cloud is shrinking, it is losing gravitational potential energy – but where does this energy leave the system? The answer lies in the fact that, as the core temperature climbs through hundreds of degrees to a thousand degrees or more, dust grains are heated by the hot gas and radiate thermally in the infrared. This radiation escapes through the cloud because the material is transparent to the infrared, thus allowing collapse to continue with a gradual conversion of gravitational energy to infrared radiation. (This is the process we invoked to explain Jupiter's IR radiation.) The black-body temperature of such radiation is several hundreds of degrees, and the peak wavelength is thus accessible to infrared astronomers. Finally, we have a fully-fledged star inside the remnants of the cloud – the star has become hot enough and dense enough at its centre to 'switch on' its nuclear reactions and to shine as a hot, young, bluish star. However, the dusty cocoon left from cloud material that did not collapse into the star still surrounds it at birth. Thus the optical and ultraviolet radiations near the peak wavelength region for the hot star (according to temperature) cannot penetrate the dust shell, so ordinary telescopes cannot see the infant star. But the dust, by absorbing this optical and ultraviolet energy, becomes heated to a temperature of, typically, 600°K, corresponding to IR radiation at a peak wavelength of about 5 microns, which escapes to the outside of the cocoon. Consequently, for most of its childhood, the 'star' is visible as an infrared object due to one, then the other, of these processes, involving *energy* leakage and the cocoon. Perhaps we should briefly consider why the infrared radiation is able to pass through the cloud or cocoon, whereas the ultraviolet rays are not. Technically, there are two reasons, namely, the 'absorption' and 'scattering' of radiation. Absorption is merely the ability of the dust grains to eat up many ultraviolet rays coming from the star, for example. Scattering is responsible, in the Earth's atmosphere, for the redness of sunsets and the blueness of a clear summer's sky. Figure 5 shows us the reason, diagrammatically. The dust grains are very efficient at pushing blue (and ultraviolet) rays from their original directions, but much less efficient when it comes to red (or infrared) rays. Hence, our sky appears blue due to the blue light of our Sun being scattered and pushed about the atmosphere. At sunset, when we look at the Sun, the red rays predominantly are able to enter our eye, travelling along their direct routes, whilst the

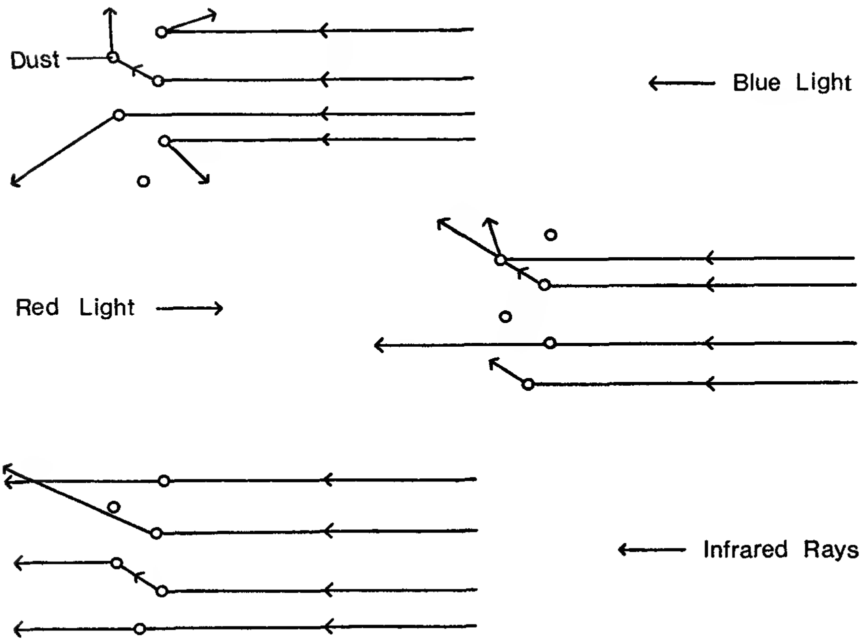


Fig. 5

blue ones have deviated from this direction. This is why infrared (a more extreme case of red) radiation can escape from dusty situations when ultraviolet (a more extreme case of blue) energy is being absorbed.

We know of one infrared source in the constellation of Orion which is quite bright in the 5 to 20 micron region but which reveals nothing but 'blank sky' to the scrutiny of even the largest optical telescope in the world. This sounds very like the proto-star described above. Recently, I have been fortunate in finding an even brighter infrared source associated with a very faint visible star – this too may be a very young star. Both of these IR sources show black-body curves of about 600°–700°K temperature.

Great interest focuses upon the future development of the cocoon; it is believed that it can become a flattish disk around the star, and this is a situation from which a planetary system may develop. We have formed a central sun, surrounded by a dusty disk, and a number of theories of the solar system's origin begin with precisely this initial state. An infrared source in Monoceros (a constellation adjacent to Orion) has radiations emitted which were interpreted, in the original discovery paper, as indicating 'a preplanetary system'.

Cool Stars

To demonstrate the variety of infrared observations we go to the other extreme in stellar evolution. In advancing age stars pass through a very luminous, cool, and extended phase called the 'giant' stage. Such a star has swelled in size until it has a radius some tens of times that of our Sun, but this has caused

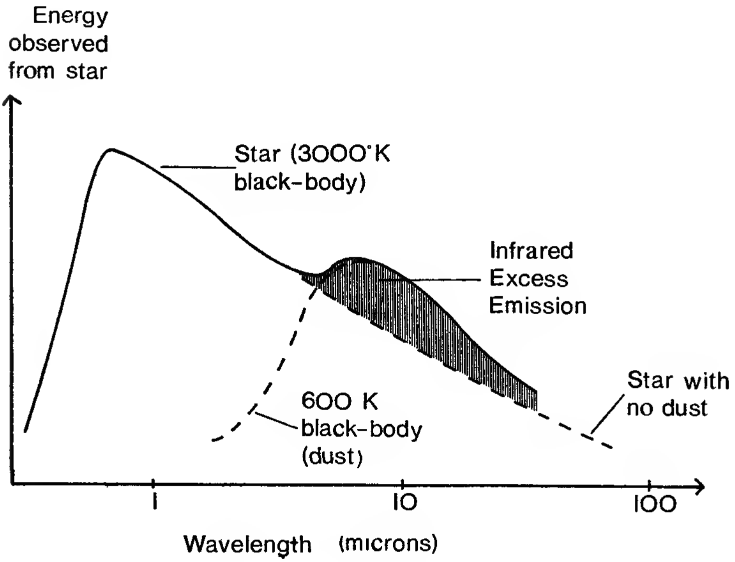


Fig. 6

the cooling of the surface to temperatures of only 3000°–4000°K, typically. For quite some time astronomers have surmised that dust grains of suitable chemical composition should be condensing out from the even cooler gases in the outer regions of cool stars' atmospheres (just as steam condenses into water droplets upon cooling). Evidence for the presence of quantities of dust surrounding cool stars has come from numerous infrared observations. The energy–wavelength figure for many stars is drastically different from a single black-body curve, and the deviations are excesses of emission, very often around 10 microns. These excesses may be represented by black-body curves of cool temperatures some 500°–700°K typically, and the interpretation of such data is that many cool stars are surrounded by quite extensive shells of dust particles, which swallow a small fraction of the central star's total energy and thus heat up, subsequently re-radiating this energy in the infrared. Such an excess of emission has also been detected from Comet Bennett, the bright, naked-eye comet visible in April and May of 1970.

Once the dust grains have condensed from the cool atmospheric gases they often find life too warm, and are expelled outwards from the star by its radiation, especially in the case of very luminous stars. It is this 'mass loss' from the atmospheres of cool stars, or during the catastrophic shedding of material in the nova phenomenon, that replenishes space with dust and other materials for the production of the next generation of stars, by mechanisms such as the one outlined in the discussion of proto-stars. The inference from these observations is that grains of the *same* chemical compositions are present throughout the Galaxy, in the dust involved in comets, in the atmospheres of cool, old stars and in the regions of space where young stars are still being born. The composition of such grains is an intriguing problem, but currently silicates are the prime candidates – substances such as magnesium silicate, although infrared excesses of other shapes are known which are more suggestive of graphite (carbon) and even iron particles.

Galaxies and Quasars

We have looked at our planetary neighbours in space, we have followed the life cycle of a star, from infancy to old age and watched as the scene was set for a new generation of stars to arise. Now we must move into the depths of intergalactic space and cast infrared eyes upon a world of wheeling galaxies, in which our own Galaxy is just one more spinning mass of stars.

We begin by taking an overall view of our Galaxy. It has been found that at the centre is a complex infrared source, with an intense component coinciding with the radio-astronomers' position for the Galactic nucleus – the hub of the disk. The precise mechanism for this infrared radiation is not yet known, but it can be classified according to its energy curve. Black-body curves (fig. 6) are due purely to heat being radiated – this is thermal radiation, whereas differently shaped curves are due to so-called 'non-thermal' mechanisms. Astrophysically, non-thermal processes are extremely important and interesting, and involve magnetic fields and electrons (or other particles) travelling at a significant fraction of the speed of light. The Galaxy seems to possess an intense non-thermal infrared source. It is important to investigate the IR properties of other galaxies and to see what emissions are observed for various galaxy types. For the Andromeda galaxy, the nearest spiral system to ours in distance, no non-thermal IR emission was detected as far as about 4 microns in 1969. However, in 1970 a series of observations was published which pushed out to the limits of ground-based IR, around 25 microns, and included some measurements at 100 microns in the far-IR, made from a stratospheric jet telescope. These data show definite detection of the nuclei of eleven galaxies, and tend to suggest a remarkable similarity for the spectral shapes of a variety of galaxy types. This common shape of the energy curves involves a sharp peak in the far-IR beyond 25 microns and, as a balloon flight in 1969 also indicated strong 100-micron radiation from our own galactic nucleus, there is growing belief in this similarity of IR emission from many galaxies. Indeed, there appears to be far more energy

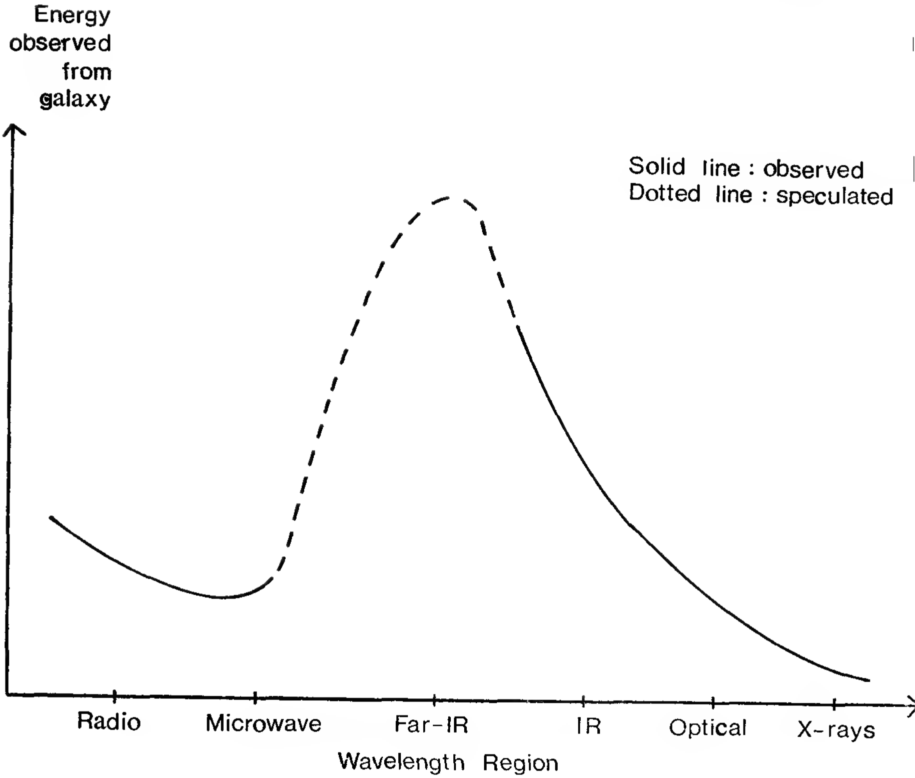


Fig. 7

emitted by these galaxies in the infrared region of the spectrum than the total power of all the stars in a typical system – a welcome bonus!

The radiation is strongest in the case of Seyfert galaxies, which are spirals in which very long photographic exposures are required in order to show the spiral arms, whereas the nucleus is extremely bright and compact. Four of these galaxies are each known to emit in the infrared an energy equal to about five hundred times the entire energy output from our own Galaxy!

For the now famous quasar 3C–273, observations indicate extreme brightness in the IR, and again this pattern occurs in which the bulk of the radiation is emitted at wavelengths beyond 25 microns. The excitement of these discoveries focuses upon ideas relating to precisely what may happen in the nucleus of a galaxy; perhaps quasars and Seyfert galaxies represent early stages in the life of a conventional galaxy and the quasar is merely a nucleus prior to the formation of spiral arms. Alternatively, catastrophic events may occur at the centres of galaxies and it is only the magnitude of the disturbance which distinguishes quasars and compact galaxies (such as Seyferts) from our own. A 'thermal or non-thermal' controversy rages at the moment and an important piece of evidence comes from time variations of these sources (some are established with fair certainty), for these limit the sizes of the objects doing the radiating. These are among the most vital unanswered questions on the frontiers of modern astronomy, and could even involve hitherto unknown physics.

The 'Big Bang'

An equally basic problem relates to the origin of the Universe; according to the 'Big Bang' cosmology (now in vogue) the entire Universe was once contained in a tiny superdense region prior to exploding and expanding away to its present state. This explosion, some ten thousand million years ago or more, will have caused the radiation of the originally inconceivably hot 'fireball' to have been degraded by now due to the expansion of the cosmos. One should find a black-body 'background radiation' now which is the same all over the sky and corresponds to the low temperature of about 3°K, if this theory is correct. Some years ago, such a background was detected in the microwave radio region; but as more data have been obtained at differing wavelengths, the black-body nature of this curve has been questioned. The relevance to the balloon-borne infrared is that 3°K has a peak of thermal emission at about 1 mm wavelength, where IR and microwaves merge, but if the peak is located elsewhere or the far-IR points (from 100 microns to 1 mm) deviate from a thermal shape then theory may need re-casting. Few matters can be more fundamental than this.

Conclusion

Modern infrared astronomy dates from about 1960, and it is apparent from the variety of the observations and their interpretations that it is a very exciting branch of astronomy. The next decade should see astronomers of all types able to meet the challenge of their own fields armed with information extending over very large regions of the electromagnetic spectrum. One looks towards the day when large infrared telescopes of 100 inches and 200 inches diameter, or possibly even larger, will provide data on sources either too faint to be adequately observed today, or demanding smaller angular resolution than can be achieved now. We have come a long way since William Herschel first was credited with discovering 'calorific rays', but these are only the initial stumbling steps along the road of infrared astronomy.

Galaxies, Peculiar Galaxies and Quasars

IAIN K. M. NICOLSON

The discrete objects which can be observed beyond the confines of our own galaxy at the present time can be classified, broadly speaking, into normal galaxies, abnormal galaxies, and quasars (Quasi-stellar Objects, or Q.S.O.s). This, in itself, is a somewhat controversial statement as it is by no means clear what is meant by a 'normal' galaxy, and there are those who would say that to make a distinction between 'normal' and 'abnormal' galaxies, given the present state of knowledge, is wholly artificial. Likewise, there is still a minority view which states that the quasars are local galactic objects, but the majority view amongst astronomers is that they are extragalactic bodies and probably located at cosmological distances. Be that as it may, one of the central questions in astronomy today is the problem of what relationship, if any, exists between the familiar optical galaxies, the radio and peculiar galaxies, and the quasars themselves. It is perhaps hardly surprising that theories abound where definitive evidence is lacking.

To begin with, let us consider the familiar types of galaxies, emitting most of their radiation at visible wavelengths. There is considerable variation in form and size, but several particular classes are apparent, namely spiral, barred spiral, elliptical, and irregular. In very general terms, we find that 'normal' galaxies have masses in the range 10^6 to 10^{12} solar masses (the mass of the sun is about 2×10^{30} kilogrammes), diameters in the range 1 to 50 kiloparsecs (one kiloparsec equals 1000 parsecs: this is equivalent to 3260 light years), and luminosities in the range

10^6 to 10^{12} solar luminosities, where the Sun itself is a star of pretty average brightness, emitting radiation at the rate of 4×10^{33} ergs per second. The brightness of astronomical bodies is often measured in terms of absolute magnitude, the apparent brightness the objects would have if placed at a distance of 10 parsecs. The sun has an absolute magnitude of +4·7 (and so would appear as a rather faint star at that distance), whereas galaxies have absolute magnitudes in the range – 10 to –25. The brightest galaxies, if 'placed' at a distance of 10 parsecs would then appear almost as bright as the Sun now appears in the daytime sky. Evidently, galaxies vary considerably in size and brightness – the smallest galaxies being comparable with the globular star clusters (of which our galaxy possesses more than a hundred), the largest several times more massive than our own galaxy (the mass of our galaxy being approximately 10^{11} solar masses).

The classification of galaxies is based on a scheme originally put forward by Hubble in 1926 and later modified by himself, Sandage and others. The classification recognizes three principal galaxy types. First, there are the elliptical galaxies which are graded from E0 (spherical) to E7 (highly flattened). E7 overlaps with the class S0, which is an intermediate stage between elliptical and spiral and shows a general flattened elliptical appearance with a hint of a disk beginning to show at the 'equator'. The spiral galaxies display a central nucleus from which two or more spiral arms of stars and matter emerge, and range from Sa galaxies with well-defined nuclei and tightly wound arms through Sb to Sc galaxies which have ill-defined nuclei and very open arms which show an irregular, clumpy, structure. A second type of spiral exists which displays a luminous bar of material straddling the nucleus, with the spiral arms emerging from the ends of this bar. Barred spirals are given as classes. SBa to SBc on the basis of similar criteria to the ordinary spirals. The final category contains the irregular galaxies, Irr, which show no discernible regular structure.

We shall now consider these classes in more detail. The ellipticals have complete rotational symmetry – in other words they are figures of revolution rotating around the small axis (oblate spheroids), and their luminosity falls off pretty symmetrically as the distance from the centre increases. It is significant that the elliptical galaxies contain practically no interstellar dust or gas, or young, blue stars of spectral classes O and B. They are very condensed, apparently old, objects and are usually attended by many globular clusters.

Spiral galaxies, such as our own, contain approximately ellipsoidal nuclei with the rest of the material confined to the galactic plane and distributed in the form of two or more spiral arms emanating from the nucleus in the case of ordinary spirals and from the ends of a luminous bar of matter in the case of barred spirals. There is considerable variation in the size of the nuclear region and the tightness of winding of the arms. At one time it was thought that the Hubble classification represented an evolutionary sequence from elliptical to tightly wound spiral (Sa) to loosely wound spiral (Sc), and superficially the idea is certainly attractive. However, this does not, in fact, appear to be the case, and it may be that there is no evolutionary link between ellipticals and spirals in either direction. Central to questions of the evolution of these galaxies is the problem of the origin of spiral structure, and interest is heightened by the fact that our own galaxy displays this spiral form. Spirals contain considerable amounts of interstellar matter as well as two basic types of stars, designated Population I and Population II, the former being younger stars (the brightest of which are predominantly blue) with high metal content, and the latter older, metal-deficient red stars. Population II stars exist primarily in the nucleus and the outer halo (which contains the globular clusters), while Population I exists in the spiral arms.

New stars are forming in the spiral arms out of the interstellar matter contained in these regions, and many of these are hot blue giants several tens of times more massive than the Sun. However, the luminosity of these stars varies as the cube of their mass, and so they may shine tens of thousands of times more brightly than our Sun. On the other hand this high luminosity means that they are using up energy hundreds, or even thousands, of times faster than the Sun and so they can shine only for a few million years. Nevertheless, because of their great luminosities, it is these stars which make the greatest contribution to the brightness of the spiral arms and, as a result, the spiral structure which we see in distant galaxies is really the distribution of these hot blue giants. It has been shown, for example by Zwicky with the galaxy M51, that the distribution of the hot blue stars in the arms is not necessarily the same as the distribution of the other types of stars in the arms. This is an additional complication to be borne in mind.

It is important to know whether the spiral arms trail (and so tend to tighten up) or lead (and thus tend to open up). Dynamical considerations by B. Lindblad showed arms would open out, but later work by P. O. Lindblad indicated that the leading-arm structure would be a temporary phenomenon, and spirals would settle into a trailing-arm situation. Other workers have attributed the spiral arms to the effects of galactic magnetic fields on the rotating galactic disk, but it does seem that in the case of our own galaxy, at any rate, the fields are too weak to explain spiral structure. C. C. Lin maintains that the underlying spiral structure is due to a density-wave pattern which rotates with the galaxy, but not at the same rate at which matter in the galactic disk rotates about the centre. The result is that particular stars do not belong to any particular arm of the galaxy but tend to cluster in the arms and move rapidly through the interarm spaces. The density of matter is always higher in the arms and the situation is reminiscent of standing waves in water. The theory has met with some success in describing the basic structure of some galaxies, e.g., M51, but the detailed structure is another matter. A final explanation will probably involve both gravitational and magnetic forces. (For a detailed discussion of spiral structure in galaxies, see the article by P. A. Wayman in the 1968 *Yearbook*.)

Irregular galaxies have no rotational symmetry and no obvious structure. There do, however, appear to be two distinguishable types of irregulars, Irr I and Irr II. Type I are normal irregulars such as the Magellanic Clouds, while Type II are peculiar objects containing much dust and obscuring matter such as M82, which is now known to be suffering the effects of a recent explosive event in its nucleus. This, in fact, leads us to the stage of discussing what I have called 'abnormal' galaxies, and before going further, something must be said about radio galaxies.

Two basic types of radio radiation can be observed, emission line radiation, such as the 21-cm radiation emitted by hydrogen gas in our own galaxy and which can be detected in nearby loose spiral and irregular galaxies, and continuum radiation. Most galaxies seem to be weak radiators of continuum radio energy. Elliptical galaxies are the weakest emitters in the normal run of events, but some abnormal E galaxies are very strong emitters. In general, radio emission increases from Sa to Sb to Sc to Irr galaxies, and this emission is in the range 10^{37} to 10^{39} ergs per second, mostly thought to be due to synchrotron radiation from supernova remnants in galactic magnetic fields (synchrotron radiation is emitted by charged particles spiralling at high velocities in magnetic fields). Strong radio sources tend to be unusually large in extent compared with the optical galaxies correlated with the sources, and very often show a double structure with one component on either side of the optical object. A good example of this is the source Centaurus A, where the radio source covers an area hundreds of times larger than the visual object (which was at one time thought to be a pair of galaxies in collision). Once again, synchrotron emission is thought to be the major energy source. Generally speaking, the strong radio sources, with radiation levels of the order of 10^{40} to 10^{45} ergs per second, tend to correlate with abnormal optical objects such as elliptical galaxies with anomalous features (such as a bright jet issuing from the main body of the galaxy), very bright S0 galaxies, galaxies with very high dust content and (often) irregular appearance, multiple galaxies, galaxies with intense star-like nuclei and faint outer envelopes, and quasars, which are essentially star-like in appearance.

In many ways the most enigmatic of the strong radio sources are the quasars. The first quasar was discovered in 1963 when the radio source 3C-273 was correlated with a blue, star-like optical object which M. Schmidt at Palomar was able to show had a red-shift of 0·158. (The red-shift is a measure of the displacement of spectral lines which takes place in the light reaching us from a receding object. The greater the red-shift, the higher the velocity of recession of the source.) If this red-shift is interpreted as a velocity of recession, then, on current theories of the expanding universe, 3C-273 lies at a distance in excess of 1000 million light-years. Many other quasars have been discovered with greater red-shifts (up to 3) which implies that they lie at distances approaching 10,000 million light-years, and are thus the most distant known objects in the universe. If quasars do lie at these enormous distances, then they are radiating as much energy as more than a hundred conventional galaxies (a total flux over all wavelengths of 10^{47} ergs per second).

Even more perplexing are the well-confirmed observations of variations in the radiation output over periods of a few months and even a few weeks. Now, since no signal can travel faster than light, this implies that the dimensions of the source responsible for the variation cannot be much greater than the period of variation multiplied by the velocity of light (since this is the time for a signal to cross the object). The surprising implication is that the vast quantities of energy emitted from quasars is coming from a region only light-months in diameter, compared with tens of thousands of light-years for galaxies. This certainly correlates with their point-like appearance. It has not been possible to determine the nature of this energy source, and in attempts to overcome the problem of finding a sufficiently powerful energy producing mechanism, it has been suggested that quasar distances are much less than they appear for one of two reasons, First, it is known that very massive bodies give rise to a gravitational red-shift, and this may account for a significant part of quasar red-shifts. Secondly, they may be local objects emitted from our own galaxy at high velocity. However, the energy required for such a process is again very high and, furthermore, since we have no reason to assume that our galaxy is atypical, then we should expect to see quasars emitted from other local galaxies, some of which ought to be approaching us, and giving rise to a blue-shift. None has been observed.

At present we are forced to regard quasars as distant and highly energetic objects and look for explanations of these enormous energy outputs. Amongst processes which have been discussed, a few are listed below:

1. Chain reactions of supernovæ in dense galactic nuclei, possibly accentuated by stellar collisions, giving rise to larger objects which evolve more rapidly to the supernova state.
2. Energy released by the collapse of objects under gravitational forces to a super-dense state.
3. Collisions between concentrations of matter and antimatter. (Matter and antimatter in collision mutually annihilate each other with the release of prodigious amounts of energy.)
4. Explanations have been suggested which are of cosmological implication, viz. that quasars may be regions where new matter is being formed, and is ‘flowing” into the universe (or indeed, the reverse may be the case).

All of these explanations present exciting physical concepts, but we are a long way indeed from a definite solution to the energy source problem, or indeed from a solution of the question of whether or not quasars represent an evolutionary phase through which all galaxies, or perhaps all radio galaxies, pass. It has, for instance, been suggested that the very high energy outputs of quasars would cause them to expand and probably evolve into radio galaxies. On the other hand, explanations of type (2) above might suggest that quasars represented the final stages in the evolution of galaxy-sized objects.

However, further interesting clues have emerged in recent years. Among the other objects which can be grouped under the heading of abnormal galaxies are the N-type galaxies (with prominent nuclei), Zwicky's compact galaxies, and the Seyfert galaxies. The Seyfert galaxies are characterized by their highly luminous, almost star-like nuclei, and rather inconspicuous outer regions. The interesting thing about the N and Seyfert galaxies is that, together with some radio galaxies, several of them have shown intensity variations in the same sort of time scale as the quasar variations. Furthermore, recent investigations at infra-red wavelengths have shown marked similarities between the spectra of radiation emitted by Seyferts and quasars, particularly between Seyferts and the quasar 3C-273B. None the less, if quasars are at huge distances, they do emit a thousand times as much radiation as Seyferts. However, if the total lifetime of a quasar is taken as a million years (and there are reasons for making this assumption), then the total amount of radiation emitted in this time amounts to some 10^{61} ergs. It is perhaps significant that this is of the same order of magnitude as the total amount of radiation emitted by strong radio sources and Seyferts in their respective lifetimes. Possibly this indicates that the energy production process may be basically the same in each case, but the time scale, and so the rate of energy production, differs from one to the other.

Turning to Seyfert nuclei once more, one of the notable features is the large quantities of infrared radiation which they emit. Infrared studies of our own galaxy show that considerable infrared radiation comes from the galactic nucleus. Possibly our own galaxy if seen from without would to some extent resemble a Seyfert in terms of its infrared output from the nucleus. Perhaps there is some link between Seyfert galaxies and processes going on in the nuclei of ordinary galaxies.

If I have painted a confusing picture, then, apart from faults of presentation, it is because the state of knowledge regarding energy processes in galaxies and quasars is at present in a somewhat confused state. Many pieces of the jig-saw puzzle are available, but as yet not sufficient to piece together the outline of the complete picture. Links do seem to be emerging between normal galaxies, abnormal galaxies and quasars, but they are vague links and the clues point towards common events in galactic nuclei. It seems likely that more intensive study of the nucleus of our own galaxy, particularly at infrared wavelengths, will go some way towards solving some of these problems in the current decade. One thing is certain, and that is that the solution of cosmological problems must depend heavily on a good working knowledge of what goes on in galaxies, and what is the origin of the signals we are receiving from the limits of the observable universe.

A Run-off Roof Observatory

R. F. SPRY

When I was recently asked to co-operate in designing and making an observatory for a 5-inch refractor, I soon found that many problems presented themselves.

It is nice to have ample room in which to operate; but larger floor-space entails greater roof area; and when the roof itself is required to disappear and reappear at short notice, size (and weight) have to be treated with respect.

With a refractor, one looks 'right through' the telescope; there is no 'side door', as with a reflector, so that a high mounting-point is required (particularly if the user happens to be tall!). With the telescope in this particular observatory, the stand – made by Charles Frank of Glasgow – was about six feet high. This meant that with the equatorial mounting, and with the telescope at horizontal rest position, at least seven feet of clearance to the roof would be required

Next, there is the question of wind force. The site of the observatory (Selsey, in West Sussex) is one of the best areas in England for viewing, with a very high percentage of clear skies. But Selsey Bill does stick well out into the Channel, and it receives more than a fair share of the prevailing south-westerly winds. However, the garden at our disposal was fairly large, and the site chosen was well sheltered on three sides by hedges ten feet high — sufficiently far from the telescope not to block the view. The remaining side, to the east, was open.

Star-gazing often means that the refractor is more vertical than otherwise, so it was worked out that a floor-base 8 feet square, with a centre pedestal 3 ft. 6 in. square raised 12 inches high for the telescope to stand on, would meet most of the requirements. On this base a framework 8 feet high was erected by a local carpenter, with good diagonal bracing of 3 in. × 2 in. timber, and covered in with light plastic corrugated sheeting.

So far, so good. Now for the roof. . . . Various ideas were given given careful consideration. Folding? Hinged this way or that, in one piece or two (or more)? Sliding, in one or more sections? Always with the thought in mind that the roof would have to be very easy to operate, usually in the dark, with due regard for the wind hazard.

The final decision was to have it in one piece, to slide on rails extended on the north side. A timber framework 8 feet square, of 3 in. × 2 in. timber covered with similar plastic sheeting, was made with three roller bearings on each side to run along the rails. These rails were two lengths of angle-iron 17 feet long, secured to the sides of the building and suitably supported on the extended portions. The brackets housing the rollers were extended down and bent under the rails to guard against wind-lift.

This worked fairly well at first trial, but the situation was much improved by fitting another roller bearing on the inside of the north face, to support the central roof-member and counter the slight sag of the 8-ft. span. A piece of thin steel strip 1 in. wide was screwed to the underside of the wood, to allow for easy running.

Now came the problem of operation. Two wooden winders with cord running over small pulleys did not prove to be very satisfactory, but served to produce further ideas. A small winch with flexible wire running over larger pulleys on the style of window or theatre curtains was the next experiment. This was certainly better, but still left room for improvement.

A central pull over such a wide span was not a good idea at all. An even pull (or push, when in reverse) on both sides at the same time was required. Using the same method would entail more wire and pulleys draped round the walls and roof; and knowing how everything will catch in everything else when not required to – especially in the dark – could a better method be devised?

Cycle-chain running over sprockets on each side of the building, connected by a shaft, and hand-wound by further chain-gear to a handle at a convenient height, seemed to be the answer, and would certainly be more dependable.

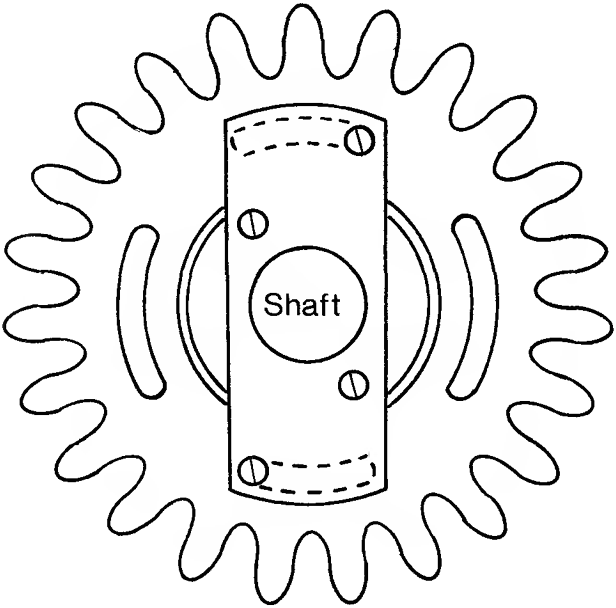


Fig. 1

Material and cost? About 40 feet of cycle chain (it is surprising how the inches mount up), 6 twenty-tooth chain sprockets, 8 feet of steel shaft of $\frac{5}{8}$ in. diameter, bearings for shaft, mounting, and crank for the hand-winder, a length of $1\frac{1}{2}$ in. steel bar for making bushes, odd pieces of angle-iron, square bar, various screws, etc., gave an estimated cost of £9, which proved to be about right. Fortunately, my workshop is equipped with all necessary tools, including a suitable lathe (a Myford ML7).

As the sprockets were designed to screw on to the cycle hubs, they required bushes to fit them, and these were tackled first. The $1\frac{1}{2}$ in. bar was reduced to $1\frac{3}{8}$ in. diameter, sufficient to take two sprockets, and threaded 24 threads per inch. Leaving a shoulder of $\frac{1}{8}$ in., the further side was reduced to 1 inch to take a set screw to hold to the shaft; it was bored out to $\frac{5}{8}$ in., and parted off. Another bar was similarly treated, with a thread

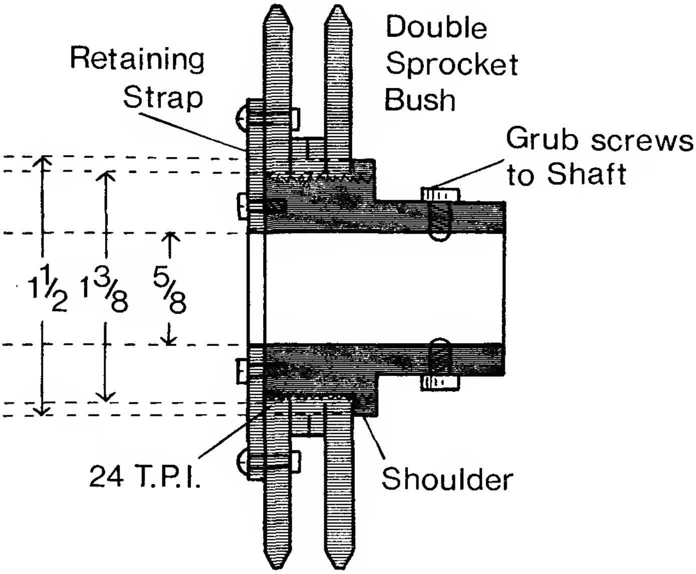


Fig. 2

for one sprocket and two bushes for the extension 'idlers'; the thread was just sufficient for the sprocket to 'shoulder on', and when screwed on tight it was secured by centre punching. There is no strain on these threads. They can be drilled or bored so as to run easily on a $\frac{5}{16}$ in. bolt, or, as I prefer, an Allen cap. These were mounted by the screw going into a short length of half-inch square bar about 2 inches long, which was screwed to the edge of a 5 in. piece of one-inch angle-iron. I used two

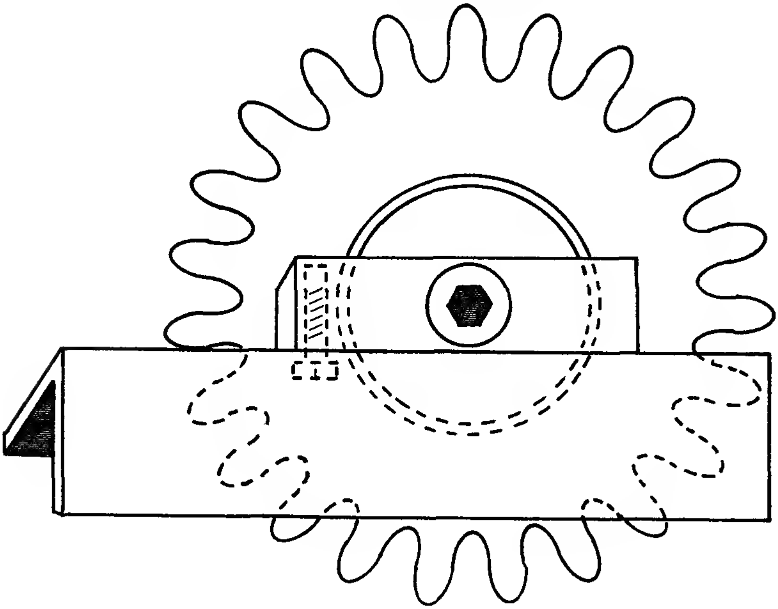


Fig. 3

countersunk 2B.A. screws from inside the angle into the square bar, so that it would fit easily on to the edge of the timber. Remembering that both right-hand and left-hand fitting was required, it was fortunate that two of the sprockets had radial slots in them; these were used at each end of the shaft, so that small plates could be fixed with short nuts and bolts, and screwed into the bushes to prevent any screwing-off. This was important, as there was bound to be a considerable strain on them when being used in reverse.

The shaft was carried in two 'Picador' alloy bearings, easily bolted to the framework. Attaching the chain to the roof in a way that would give me satisfaction caused a good deal of thought. Various ideas were rejected, as they tended to limit the full amount of travel. Then, when the chain was lying on the bench, it was pushed aside and I noted that one link doubled up on itself, making a triangle. That solved the problem. The rivet *B* is punched out of the half-link *A* (though sometimes the rivets are extra hard, and it is advisable to grind off the head of the rivet to make removal easier and avoid damage). The inner link *C* has a hollow rivet *D*, which also is removed. A simple special punch was made for this, and the hollow rivet was carefully retained; the roller *E* was discarded.

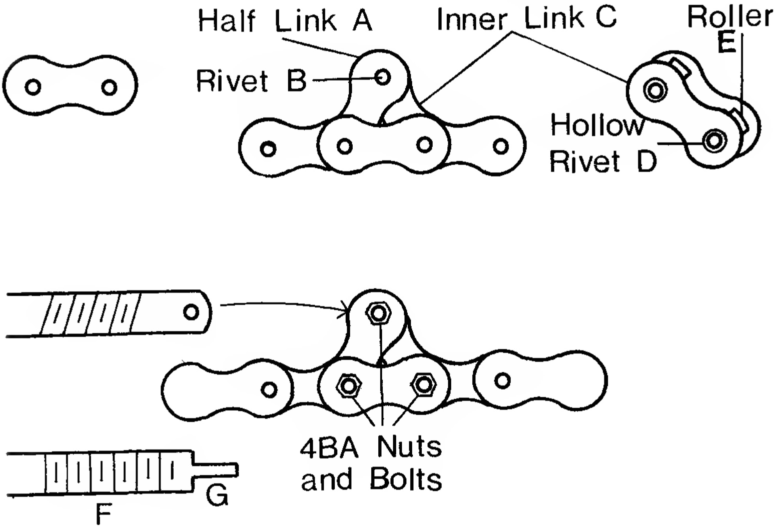


Fig. 4

The rivet-hole *B* was No. 26 drill size (0·147), and the hollow rivet hole *D* was No. 5 (0·2055); so the draw rod *F* was drilled with a No. 5 at *G*, and the hollow rivet inserted. Links *A* and *C* were then rejoined, with the end of the draw-rod between, and a 4B.A. nut and bolt replacing rivet *B*. The draw-rods were two pieces of $\frac{1}{2}$ in. screwed rod (studding), each 4 in. long, filed to give a flat section $\frac{1}{2}$ in. long by $\frac{1}{8}$ in. thick at one end. These were passed through a piece of $\frac{3}{4} \times \frac{1}{8}$ in. plate at each side of the back timber of the roof, and with a nut on each side allowed for any small necessary adjustment of tension. With this triangle jutting out from the chain, it allowed the push-pull to operate to the full extent of the traverse.

For the hand-crank, the 'odds-and-ends-come-in-handy' boxes were raided, and produced a Picador grinding/drilling head and a left-hand cycle pedal crank. One more bush for the last sprocket to fit on to a short piece of $\frac{5}{8}$ in. shaft, a handle fitted to the pedal spindle hole, and there was the hand-winder ready to fit.

The observatory was completed in late 1970. At the time of writing (March 1971) it has given no trouble at all; it is easy and convenient to use, and I think I can say, with all modesty, that the design is a suitable one for a refractor of this size.

The Newtonian Flat and Its Mounting

H. WILDEY

The optical quality of the small elliptical mirror known as the Newtonian flat is as important as the large circular image-forming mirror if one is to get the best out of a telescope. Often, when an instrument gives a bad image, it is the main mirror that is suspected. Many times it can of course be both components, as the maker of a bad mirror is hardly likely to spend much time on the flat! In many cases, however, the mirror is quite good, and the trouble turns out to be that the flat is just a piece of unworked plate glass. To be of any use it should not deviate from a truly flat surface by a quarter of a wave or better, and unfortunately there is no way, short of testing it, to know if it is good or not. A bad one can be beautifully edged to a forty-five degree slice shape with a good polish and still be useless. Good makers who are proud of their work often sign on the back face; and if it bears a well-known name, this can give confidence to a would-be buyer.

Assuming you have a good flat, the next thing is to mount it into the centre of the tube. In poor-quality instruments it is often stuck with epoxy resin on to a piece of wood or metal. This is bad practice, as these substances have a different expansion ratio to the glass, so that it is always under strain and stress and the image will suffer. Also, after a time, the flat's surface will require re-coating, which means that the old film must be removed and replaced by depositing a new, bright aluminium surface. This has to be done in a very high-vacuum chamber, and it will have to be got off its holder for this purpose; and with the strong cement required to hold it on, it will be difficult to get it off. Sometimes the flat gets broken.

The proper way to mount the flat is to get a piece of brass tube with an inside diameter a shade larger than the minor axis of the flat. With a fine hacksaw cut off the end at an angle of forty-five degrees and silver-solder a small lune of brass across the sharp end. Cut the tube squarely across to the correct length allowing for the thickness of the heel of the flat. The flat should not be thin; I like half-inch for usual sizes, and I like to make a flat face on its heel, as this cuts down the length of the tube

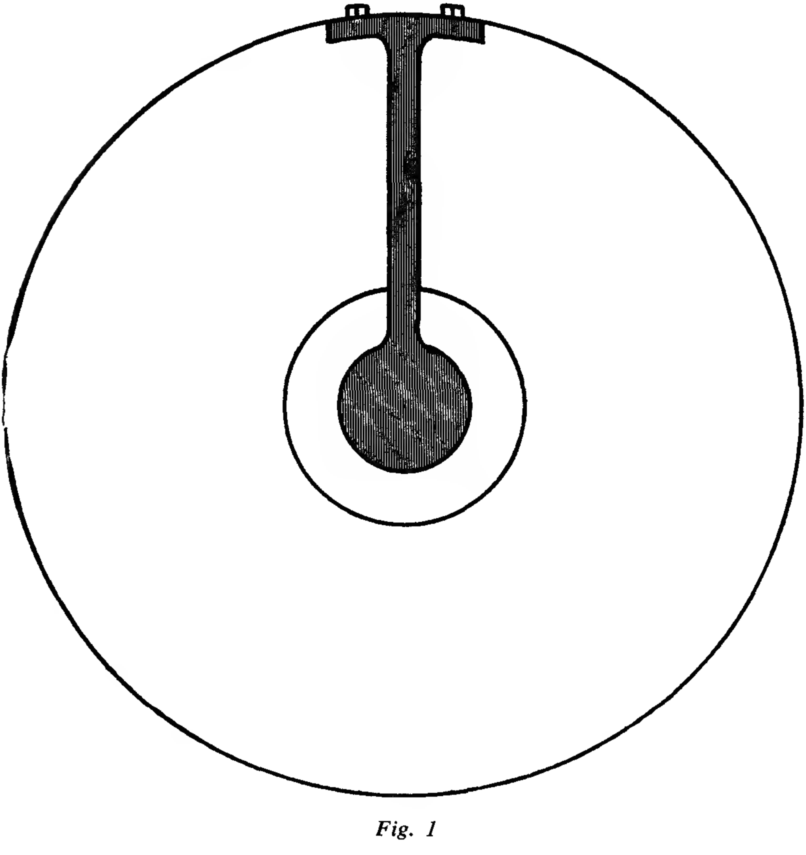


Fig. 1

and gives a surface for the retaining spring to press on. The brass lune is quite sufficient, with a thick flat, to stop it falling through, and the spring just touches to stop it getting out of position; it is important that it exerts no pressure, nor must the flat be pinched by the sides of the tube, as otherwise it will distort. (I may add that this applies to all optical components.)

We now have to consider the best way of holding the flat in its holder in position at the mouth end of the tube. The component that does this is called the spider. Not only must it hold the flat in its holder rigidly in place, but it must also permit it to go up and down and in all other directions, so that it can be squared-on optically with the main mirror and eyepiece, which is essential to get good images. This calls for one or more arms from the inside of the tube to the body of the spider, and as these arms must cross the beam of the main mirror they will produce an effect on the image known as diffraction rays. Some people use a single arm going half-way across, that is to say, from the inside of the tube to the spider's body (fig. 1). This arm has to be very strong and rigid if it is to hold the flat exactly in place; and with repeated uncapping and capping every time the telescope is used, it will probably not stay in position for long. Things can be improved by making the arm go right across (fig. 2); any bright object will show a diffraction ray which will be the same if the arm goes half-way or right across.

Older instruments had three-armed spiders, the arms being set at 120 degrees (fig. 3). This holds the flat more rigid, and at first appearances would seem ideal, but unfortunately the arms have to be tensioned, and as each half arm gives a bright ray we are saddled with a six-rayed image – which, to say the least, is more than is to be desired.

The modern way is to use a four-armed spider (fig. 4). This gives a two-rayed image, and is seen in most of the photographs taken with large reflectors, where, if a bright star is in the field, it appears as a 'X'.

The four arms can be formed by two strips of metal bent to

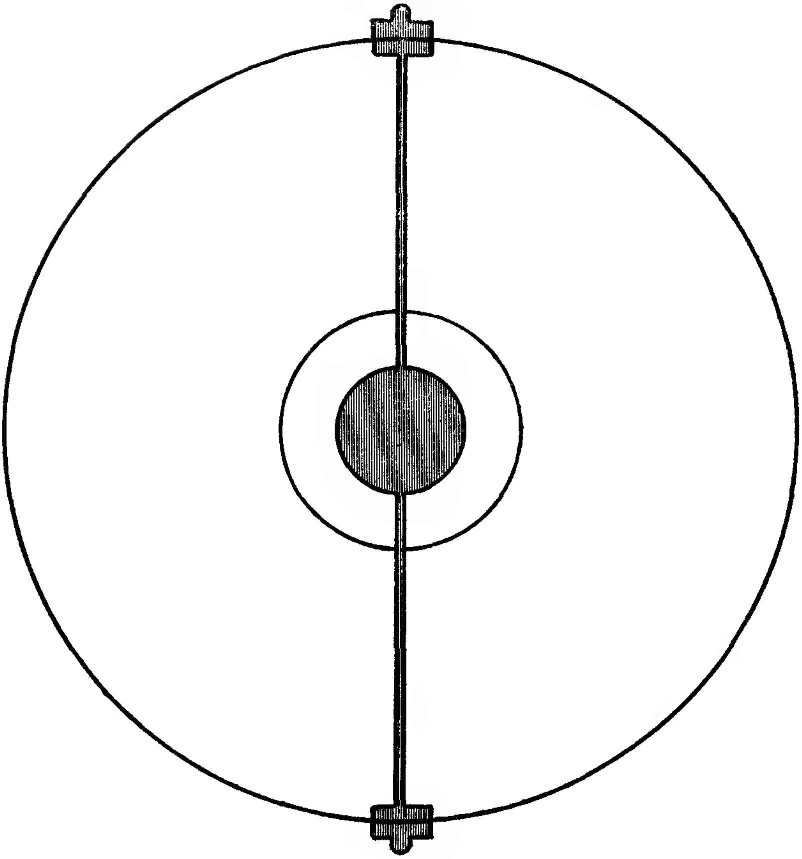


Fig. 2

right angles to form a 'V' with the point screwed to either side of the spider's body, and the ends screwed to the tube. The old three-armed spiders had arms of spring steel, but the four-armed system does not need tension, and so is best made of brass or dural strip. In fact, I think the whole thing is best made of non-ferrous material as otherwise hard rust fragments can

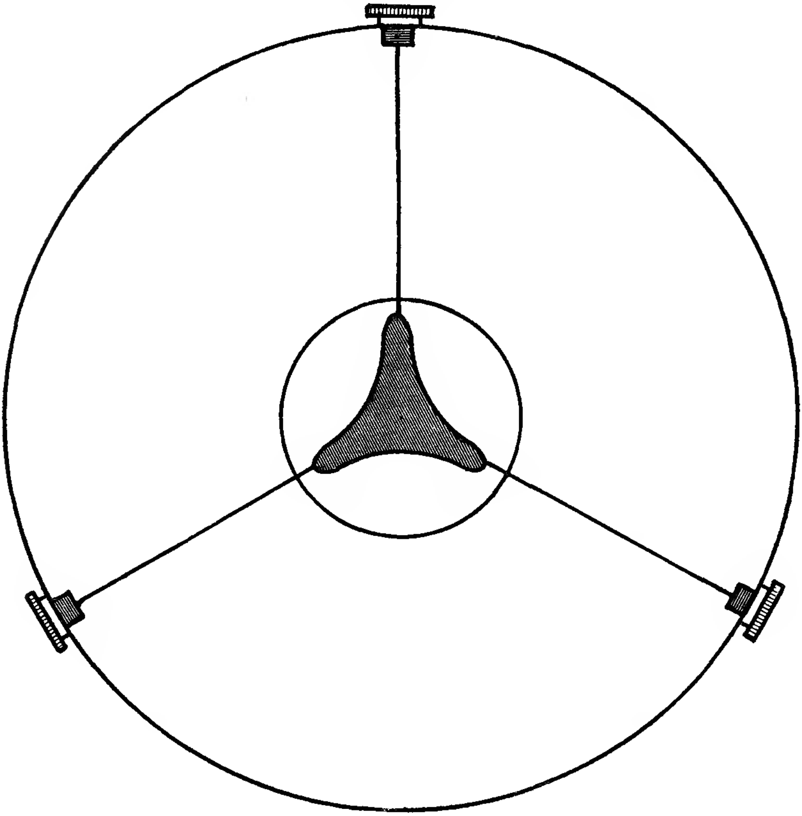


Fig. 3

fall on to the mirror, and the heads of steel screws can be missing when you want to remove them, giving a lot of trouble. The slight extra cost is well worth while in the end.

Finally, do not make the flat too small. The common Japanese reflector with a 4½-inch mirror has a flat with a minor axis of only ¾-inch. This is far too small to take in the full beam, and means that all the outer portion of the mirror is wasted. To have increased the minor axis to, say, 1¼-inch would

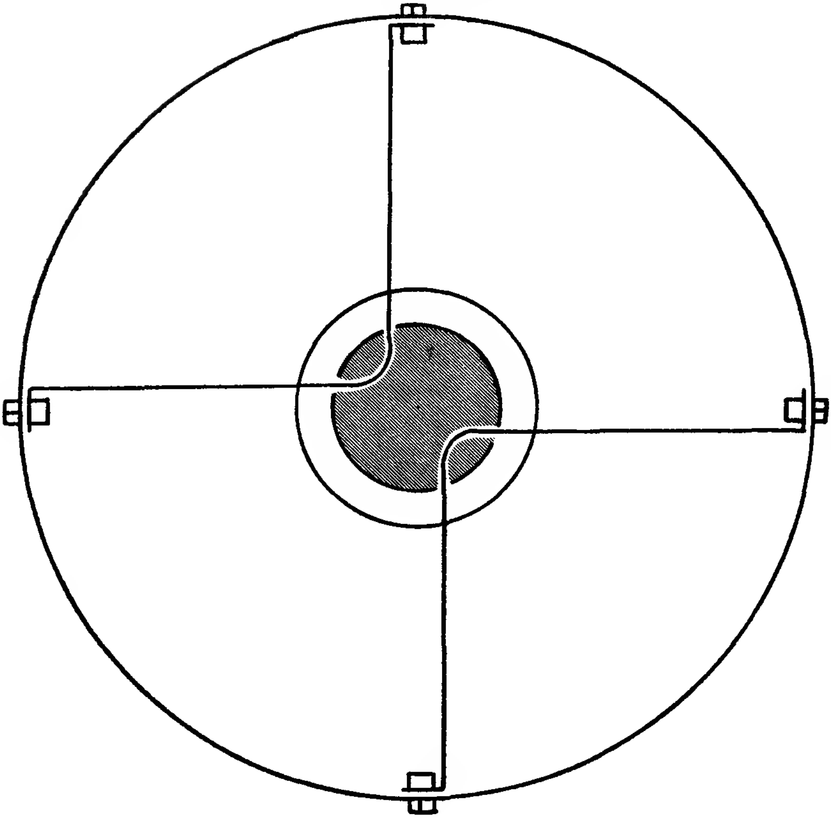


Fig. 4

have obstructed less than a square inch – but think how many square inches are lost in not having the light collected by one inch all round the edge of the mirror! Diagrams often show the beam from the mirror at the focus, but this is true only for a single star, and if the size of the flat is deduced from this it is incorrect. The image the mirror is producing has a diameter as large as the field lens of the lowest-powered eyepiece, say 1-inch to ¾-inch, and if you are tracing the cone back you should start with this measurement and not a point.

A thing that seems to bother telescope constructors is where to position the flat. This can be found simply enough by measuring the distance from the centre of the tube to its outside, plus the length of the focusing mount with the draw tube extended about an inch. Deduct this distance from the focal length of the mirror and the figure you are left with is the distance from the centre of the mirror to the centre of the flat. For example, if you have a 6-inch mirror of 40-inch focus, and the tube has an external diameter of 7 inches, then half of this is 3½ inches. The length of the focusing mount with 1-inch extension is 5½ inches, which, added to 3½ inches will give 9 inches. 40 inches less 9 inches gives us 31 inches, and so the distance from mirror to flat will be 31 inches.

Recent Developments in Astronomy

PATRICK MOORE

Astronomy and space research continue to advance at a remarkable rate. Unfortunately, it takes much longer to print and produce a book now than it did a few years ago. This means that it is increasingly difficult to be entirely 'up to date', and I must stress that the present article is being written in July 1971. Much may have happened before this *Yearbook* is in your hands, in the late autumn; but already 1971 has been an important year.

So far as space developments are concerned, there have been three notable triumphs. Lunokhod 1, the strange Russian vehicle which has a look of improvisation and old-fashionedness about it (it has been likened to a hansom cab!) has proved to be startlingly efficient. It was deposited on the Moon, from Luna 17, on 17 November, 1970, and at once began its tour of exploration, moving around on its eight independently-powered wheels and being guided by controllers on Earth. It sent back information of all kinds, together with detailed photographs of excellent quality. Its programme was scheduled to end in February 1971, but its performance far exceeded its makers' expectations. By the end of June it was still fully operational, still capable of movement, and still sending back data. There are grounds for supposing that from a technical point of view this is the greatest Russian space-success yet.

The first true space-station, Salyut, was of course more spectacular. Salyut was launched unmanned, and was then inspected by three astronauts in Soyuz 10 (Shatalov, Yeliseyev and Rukavishnikov), who docked with it for five and a half hours before returning to terra firma. Subsequently Soyuz 11 took up Cosmonauts Dobrovolsky, Volkov and Patsayev, who entered Salyut and began a prolonged period of scientific research. Particular attention in the early part of the programme was paid to the Earth; its ice-caps, its weather systems and so on. Just as this final section of the *Yearbook* went to press, there came the tragic news of the deaths of the three cosmonauts, who lost their lives during the final descent of Soyuz 11. The Russians have stated that a leak in the capsule was the cause. Messages of sympathy have been pouring in to Moscow; for a brief moment it seems that the whole world has been united. Certainly the gallant trio will never be forgotten.

On the American side, we have had the February triumph of Apollo 14, which landed in the Fra Mauro highlands. The crew consisted of Alan Shepard and Edgar Mitchell, who reached the Moon, and Stuart Roosa, who remained in the orbiting command module. The trip was entirely successful, and put the U.S. space programme 'right back on course'. A lunar 'cart' was taken almost to the rim of a sizable crater, Cone Crater; experiments were deposited on the Moon; observations were made, and lunar samples brought home. For Shepard it was a double triumph. Ten years earlier he had been America's first man in space, when he undertook a brief sub-orbital hop in a Mercury capsule; subsequently he had been taken off the active list because of ear trouble, and had regained his place in the team only by his remarkable courage and will-power. He also became the first lunar golfer, but here it seems that he over-estimated his prowess. Millions of listeners on Earth heard him exclaim that the golf-ball had gone 'miles and miles and miles'. Alas, photographs taken by the astronauts were subsequently examined—and the golf-ball was found only 20 yards away. It has been suggested that Colonel Shepard may have at least one thing in common with Vice-President Agnew: a slice!

Following their success with the planetary probe Venera-7, the Russians dispatched two vehicles toward Mars: Mars-2 and Mars-3. As yet (July 1971) no official account of their rôle has been released, but since both probes are massive it is likely that they are intended soft-landers, in which case one must hope that they are effectively sterilized. America's Mariner 8 failed on 8 May, 1971, and landed unceremoniously in the sea, but on 28 May Mariner 9 was launched on schedule. Results from all these probes should be received around November. Mariner 9, of course, is not meant to achieve a landing; it will enter an orbit round Mars, and should have an active lifetime of many months.

In this connection, it is fascinating to note that Mariners 6 and 7, which by-passed Mars in August 1969, were still being used as deep-space probes in 1971. One investigation in which they have been involved concerns the supposed gravity waves to which attention has been drawn by J. Weber. Dr A. J. Anderson has attempted to measure the physical effects of these waves on the positions of Mariners 6 and 7. The experiment is not easy, because at the beginning of 1971 the two probes were about 150,000,000 miles from Earth, and Anderson was looking for displacements of a few centimetres! It has been said that the procedure is roughly analogous to that of detecting sea-waves by measuring the displacements which they produce on floating rafts. Anderson's preliminary results appear to be positive, though it is, as yet, too early to come to any hard and fast conclusions.

Needless to say, space results make up only one branch of astronomy, and simply because the space programmes are spectacular it would be a grave mistake to suppose that they are all-important. Our knowledge of the universe is derived mainly from Earth-based observations, and it is not surprising that there are developments in telescope-building. The 236-inch reflector being constructed by the Russians has reached the testing stage, and there are hopes that it will be fully operational within the next two years. Elsewhere there is considerable emphasis on telescopes which are sited far enough south to study objects of exceptional interest such as the Magellanic Clouds. Cerro Tololo, in the Chilean Andes, has a 150-inch telescope nearing completion, and there are plans for a 100-inch reflector at Las Campanas, also in Chile. The recent political changes in that country have given some cause for concern, but in every other way Chile is astronomically ideal; tests have shown that it is the most favourable of all sites in the southern hemisphere.

Few years pass by without some new discovery in the field of pure astrophysics. One, of special interest, concerns the element promethium, which is unstable; it has never been found naturally, though it has been produced in our laboratories. It has a half-life of 18 years, and so on the cosmical scale it disintegrates very quickly indeed. None the less, spectral lines due to promethium have been found in at least one star by two Michigan astronomers, C. Cowley and M. Aller. It follows that promethium must be constantly synthesized near the star's surface.

The problem of Epsilon Aurigæ is quite different. Some notes on the new theories about it will be found on pages 56 and 57 of this *Yearbook*. The collapsar idea has been challenged; for instance, in 1971 Demarque of Yale University and Morris of the Dominion Astrophysical Observatory in Canada strongly supported the theory that the invisible companion is not a collapsar at all, but merely an ordinary star which is surrounded by a cloud of cool gas. However, Epsilon Aurigæ may not be unique; there is a good chance that another system, 89 Herculis, is of the same kind.

Of course, pulsars and quasars continue to be very much in the forefront of astronomical research. It is important to remember that there is no connection between these two types of objects, and the similarity in the names is rather unfortunate. Pulsars are members of our Galaxy, and we have at least one reliable distance-measure; there is a pulsar in the Crab Nebula, which we know to be about 6000 light-years away (a revision of the older value of only 4000 light-years). Quasars, whatever they may be, are more remote than that; and they are extremely luminous. As is described in Iain Nicolson's article in this

Yearbook, the general consensus of informed opinion is that they are the most remote objects known to us.

Pulsars, on the other hand, are normally detectable only by their long-wavelength emissions. The only pulsar optically identified is that in the Crab. Recently, however, there has been another important discovery—and again we come back to space research, because the discovery was made by means of instruments carried on board the U.S. satellite Explorer 42. What Explorer 42 has done is to detect a new 'X-ray pulsar', now known as Cygnus X-1. It emits X-rays in bursts at a rate of 15 per second. Can this object, too, be a collapsar, so that the X-radiation comes from a cloud of material spiralling round the 'black hole' and in toward it? This has been proposed by R. Giaconni; but again the theory is very tentative. Of course, the Crab Nebula too is an X-ray source. And going beyond the Galaxy, we find X-radiation coming from at least one quasar (3C-273) and various Seyfert galaxies. It is a pity that all this research has to be carried out by equipment taken above the screening layers in our atmosphere; certainly the setting-up of an observatory in a space-station, or on the surface of the airless Moon, will be a boon to researchers.

Meantime, the Russians have managed to detect the first extra-galactic source of gamma-radiation. This has been achieved by S. Volobnev, A. Galper, V. Ugryumov, B. Luchkov and Y. Ozerov, all of Moscow. Special gamma-ray telescopes were launched in Cosmos 251 and 264, and the satellites were set to spin slowly so that the equipment would scan a 35-degree-wide band all round the sky. Results showed a source in a zone measuring 20 degrees by 5 degrees. Right in the middle of this area was the unusual galaxy 3C-120, and there seemed to be a connection between the gamma-radiation and bursts of long-wavelength radiations from this galaxy. Therefore it is reasonable to assume that 3C-120 is responsible for the gamma-rays, even though definite proof is still lacking. Gamma-ray astronomy is still at an early stage, but the Moscow results may provide a basis for future investigations.

Another interesting discovery has been that of two new members of our local group of galaxies. Maffei 1 and 2, as they are called (in honour of the Italian astronomer who first drew attention to them), seem to be about 3,000,000 light-years away. They are large—perhaps as large as the Andromeda Spiral, and in this case superior to our own Galaxy. They have not been identified before simply because they lie in the so-called 'zone of avoidance' near the Milky Way, and are heavily obscured and reddened by interstellar matter in our own Galaxy. It is interesting to speculate as to how many more unknown members of the local group may exist, hidden permanently from our view.

Looking back only a decade, it is amazing to see how much has happened. When the first *Yearbook* came out, in 1962, quasars and pulsars were not only unknown, but also unsuspected; extragalactic radio sources were still thought to be due to cosmical collisions; no successful planetary probe had sent back its results; and there were still people who ridiculed the idea of landing men on the Moon much before the end of the century. Astronomy has changed vastly from the static science which it used to be many years ago, and as yet there is no sign of any slackening in the rate of progress. We live in exciting times.

PART THREE

For Stellar Observers

Stars of the South

PATRICK MOORE

The star-maps in the main body of this *Yearbook* are drawn for observers who live in the northern hemisphere. This has also been the case for all previous editions, which is reasonable enough; but there are occasional complaints that readers who live in the southern part of the world are badly left out! This too is reasonable. A compromise may be to say something here about the constellations which are never visible from Europe or most of the United States, together with some notes about the unfamiliar aspects of familiar groups.

From South Africa and Australia, and of course New Zealand, the Great Bear, Ursa Major, can never be seen. (A few of its stars rise, but to all intents and purposes it is out of view, though it can be observed from countries such as Rhodesia, which are closer to the equator.) Orion is naturally visible, since the celestial equator runs through it; but Europeans are struck with the apparent strangeness of seeing Rigel higher than Betelgeux, as shown in fig. 1! Also, Orion is a summer group, remembering that southern summer occurs around Christmastime.

Sirius rises high in the sky, with its brilliance even further enhanced. It alone surpasses Canopus, in Carina – the keel of the Ship, Argo Navis, a constellation so huge that it has been unceremoniously dismembered. Canopus can be found from Orion by using Zeta and Kappa Orionis as 'guides', but it needs little identification, because it is so bright. Its magnitude is −0·7, far superior to Capella or Vega. Since its spectrum is type F, it should be yellow in hue; but I admit that I can see no colour in it, either with the naked eye or telescopically. To me it seems white.

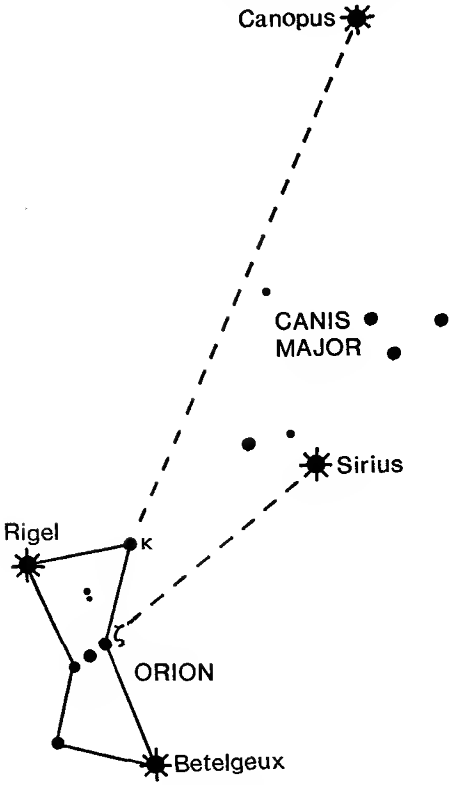


Fig. 1

Carina is a glorious, rich constellation with many interesting objects. One of these is Eta, the erratic variable, which during the nineteenth century blazed up to rival Canopus, but is now below naked-eye visibility. It is involved in extensive nebulosity, well seen with binoculars and magnificent in a telescope.

The star known officially as Beta Carinæ, with its little-used proper name of Miaplacidus, is above the second magnitude. Sirius, Canopus, Beta Carinæ, and the Southern Cross, Crux

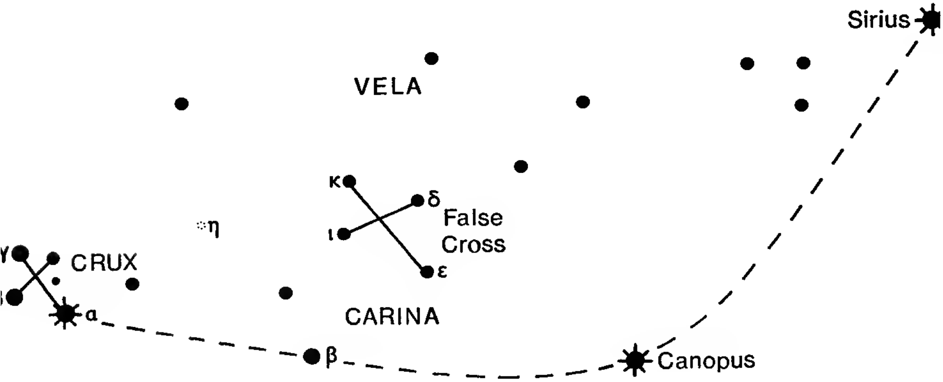


Fig. 2

Australis, make up a superb curved 'sweep' across the sky (fig. 2).

Who has not heard of the Southern Cross? It is the smallest constellation in the entire sky, but it is also perhaps the most spectacular. Two of its stars, Alpha (Acrux) and Beta, are of the first magnitude; Gamma 1½. Delta, the remaining member of the quartet, is considerably fainter, which gives the group an unbalanced appearance; one must admit that it is more like a kite than a cross (fig. 3).

Actually, there is very little difference in brightness between Beta and Gamma, but the two are dissimilar. Beta, like Alpha, is a hot white star of type B; Gamma is an M-type red giant. Binoculars show the contrast beautifully. 'Acrux', the proper name for Alpha Crucis, seems to be a modern term; at any rate the star is a magnificent binary, and a third star lies in the same field, making up a group never to be forgotten. Also in Crux we find Kappa Crucis, the 'Jewel Box' cluster. Binoculars show it unmistakably, but a telescope is needed to bring out its full beauty, with its stars of varied colours. To complete the picture we have the Coal Sack, the best example of a dark nebula in the entire sky.

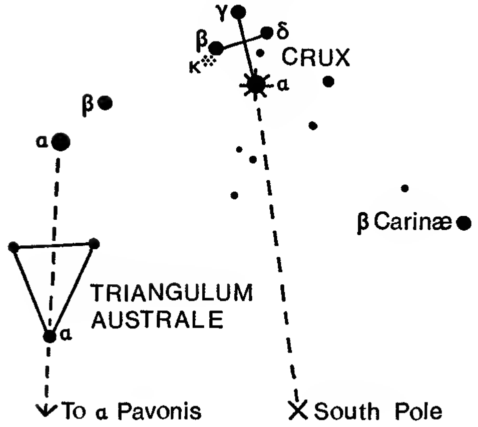


Fig. 3

Close by Crux are its 'pointers', Alpha and Beta Centauri. Alpha Centauri is a mere 4·3 light-years away; Proxima, our nearest stellar neighbour, is a dim companion of the Alpha Centauri system. Alpha is itself a fine binary, separable in a small telescope; the components are somewhat unequal, but with the naked eye combine to produce a star which is surpassed only by Sirius and Canopus. Beta, of type B, is very luminous and remote, so that it has no connection whatsoever with Alpha even though the two appear to lie side by side in the sky.

Incidentally, I have never found any real danger of confusion between Crux and the 'False Cross'. The False Cross lies in Argo; two of its stars (Kappa and Delta) are in the Sails, Vela, while the other two (Iota and Epsilon) are in Carina. All are of the second magnitude; Epsilon is strongly orange, and close to it is a rich cluster.

Centaurus contains many other notable objects in addition to its two leaders. For instance, there is Omega Centauri, the sky's finest globular cluster, beside which the northern Hercules

Globular seems very dim. Omega Centauri is prominent with the naked eye; binoculars show it well; with a telescope it is remarkable, with its almost countless stars.

Crux and its region are circumpolar from most of the populous countries of the southern hemisphere, though from places such as South Africa they can skirt the horizon. They are at their best in winter evenings (northern summer!) when, however, much of the northern aspect is covered by Hydra, which is very barren of bright stars. Spica and Arcturus are also in evidence. Corvus, the Crow, is more prominent than most northerners realize; the longer 'axis' of Crux points toward it.

Before leaving Centaurus, take note of a constellation close beside Alpha. This is Triangulum Australe, the Southern Triangle — whose name really does indicate its aspect! Alpha Trianguli Australe, of magnitude 1·8, is strongly orange.

In one respect northern observers have an advantage over their southern colleagues. There is no bright south polar star; the fifth-magnitude Sigma Octantis is no substitute for Polaris. The south celestial pole may be found by using the Cross as a guide, as shown here; but it is a region devoid of bright stars, and is occupied by various small, modern constellations.

Yet the lack of a polar star is more than compensated for by the two Magellanic Clouds, which look rather like broken-off parts of the Milky Way, but which are in fact separate star-systems or independent galaxies. Both are naked-eye objects, and the Large Cloud shows up even in moonlight. It contains objects of all kinds, including open clusters and gaseous nebulæ. If the largest nebula of the Cloud were as close to us as the Great Nebula in Orion, it would cast shadows – but it is in fact 180,000 light-years away. In the Cloud, too, is S Doradûs, a variable star which is the equal of a million Suns, and yet shines as no more than an object of the seventh magnitude.

There is nothing in the northern sky to compare with the Clouds. To astrophysicists, and indeed to astronomers of all kinds, they are of supreme importance, which is one reason for the present-day concentration upon setting up large telescopes in the southern hemisphere of the Earth. Neither Cloud can be studied from Mount Wilson or Palomar.

Not far from the Clouds we find Achernar, the leader of Eridanus, which acts as a 'skymark' to the area. Part of Eridanus can, of course, be seen from Europe; the third-magnitude Beta is near Rigel. However, Achernar is much too far south, and so is the other really interesting star in the constellation, Theta or Acamar. Ptolemy and other astronomers of classical times ranked Acamar as of the first magnitude. It is now of the third, and there are suggestions that it may have faded, though the evidence is rather dubious. At any rate, it is a fine binary, separable with a small telescope. Neither must we overlook Fomalhaut, in Piscis Austrinus (the Southern Fish), which is always low as seen from Europe or the northern United States. When high in the sky, as observed from the southern hemisphere, it is very striking. Between it and the horizon lies

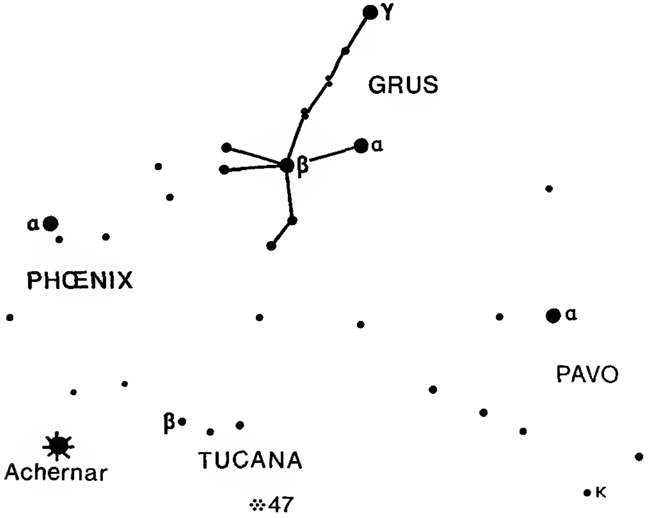


Fig. 4

Pegasus; but Andromeda, with its Great Spiral, is to all intents and purposes lost to view.

In spring evenings (around November) the 'Southern Birds' are high up. These are Grus, the Crane; Phœnix, the Phœnix; Pavo, the Peacock; and Tucana, the Toucan (fig. 4). Only Grus is distinctive. Here we have a pattern which can really be twisted by the imagination into the shape of a flying crane; of its two second-magnitude leaders Alpha (Alnair) is bluish-white, Beta glorious orange. In the line there are two 'pairs' of stars, and once it is identified the constellation will not be forgotten. This is fortunate, since the other Birds are less distinctive, and the whole area can cause confusion. I have found that a good pointer can be made from Alpha Centauri and Alpha Trianguli Australe. If continued far enough, this will lead to the second-magnitude Alpha Pavonis, which is rather on its own. Pavo also contains Kappa, one of the brightest of the galactic Cepheid variables; Tucana has a globular cluster (47 Tucanæ) which is the finest in the sky apart from Omega Centauri, and is easily seen with the naked eye. Beta Tucanæ is a wide, easy double.

Finally, we must say a word about Scorpio (or Scorpius) and Sagittarius. From Europe and the northern United States, neither constellation is seen to advantage. From the south, they show up splendidly. Sagittarius is admittedly rather shapeless; but Scorpio is a superb group, led by Antares and with its characteristic 'sting', one of whose members, Lambda (Shaula) is only just below the first magnitude. When Scorpio is seen almost at the zenith, its true glory can be appreciated to the full. Look for it there during evenings in August or September.

This review of the southern sky is hopelessly sketchy and incomplete; to do it justice would need very many pages. But I hope that it does at least give some indication of what is to be seen, and that if you 'go south' during 1972 you will not forget to look upward to see for yourselves the beauty of the Centaur, the Ship, the Scorpion, and, above all, the Southern Cross.

Some Interesting Telescopic Variable Stars

Star	R.A.		Dec.		Mag. range	Period, days	Remarks
	h	*m*	°	′			
R Andromedæ	0	22	+38	18	6·1–14·9	409	
W Andromedæ	2	14	+44	4	6·7–14·5	397	
R Aquilæ	19	4	+ 8	9	5·7–12·0	300	
R Arietis	2	13	+24	50	7·5–13·7	189	
R Aurigæ	5	13	+53	32	6·7–13·7	459	
R Boötis	14	35	+26	57	6·7–12·8	223	
R Cassiopeiæ	23	56	+51	6	5·5–13·0	431	
T Cassiopeiæ	0	20	+55	31	7·3–12·4	445	
T Cephei	21	9	+68	17	5·4–11·0	390	
Omicron Ceti	2	17	− 3	12	2·0–10·1	331	Mira.
R Coronæ Borealis	15	46	+28	18	5·8–14·8	–	Irregular.
W Coronæ Borealis	16	36	+37	55	7·8–14·3	238	
R Cygni	19	35	+50	5	6·5–14·2	426	
U Cygni	20	18	+47	44	6·7–11·4	465	
W Cygni	21	34	+45	9	5·0– 7·6	131	
SS Cygni	21	41	+43	21	8·2–12·1	–	Irregular.
Chi Cygni	19	49	+32	47	3·3–14·2	407	Near Eta.
R Draconis	16	32	+66	52	6·9–13·0	246	
R Geminorum	7	4	+22	47	6·0–14·0	370	
U Geminorum	7	52	+22	8	8·8–14·4	–	Irregular.
S Herculis	16	50	+15	2	7·0–13·8	307	
U Herculis	16	23	+19	0	7·0–13·4	406	
R Hydræ	13	27	−23	1	4·0–10·0	386	
R Leonis	9	45	+11	40	5·4–10·5	313	Near 18, 19.
X Leonis	9	48	+12	7	12·0–15·1	–	Irregular (U Gem type).
R Leporis	4	57	−14	53	5·9–10·5	432	'Crimson star.'
R Lyncis	6	57	+55	24	7·2–14·0	379	
W Lyræ	18	13	+36	39	7·9–13·0	196	
HR Delphini	20	40	+18	58	3·6– ?	–	Nova, 1967.
Nova Vulpeculæ	19	45	+27	2	4·8– ?	–	Nova, 1968.
U Orionis	5	53	+20	10	5·3–12·6	372	
R Pegasi	23	4	+10	16	7·1–13·8	378	
S Persei	2	19	+58	22	7·9–11·1	810	Semi-regular.
R Scuti	18	45	− 5	46	5·0– 8·4	144	
R Serpentis	15	48	+15	17	5·7–14·4	357	
SU Tauri	5	46	+19	3	9·2–16·0	–	Irregular (R CrB type).
R Ursæ Majoris	10	41	+69	2	6·7–13·4	302	
S Ursæ Majoris	12	42	+61	22	7·4–12·3	226	
T Ursæ Majoris	12	34	+59	46	6·6–13·4	257	
S Virginis	13	30	− 6	56	6·3–13·2	380	
R Vulpeculæ	21	2	+23	38	8·1–12·6	137	

Some Interesting Double Stars

The pairs listed below are well-known objects, and all the primaries are easily visible with the naked eye, so that right ascensions and declinations are not given. Most can be seen with a 3-inch refractor, and all with a 4-inch under good conditions, while quite a number can be separated with smaller telescopes, and a few (such as Alpha Capricorni) with the naked eye. Yet other pairs, such as Mizar-Alcor in Ursa Major and Theta Tauri in the Hyades, are regarded as too wide to be regarded as bona-fide doubles!

Name	*Magnitudes*	*Separation,"*	*Position angle, deg.*	*Remarks*
Gamma Andromedæ	3·0, 5·0		060	Yellow, blue. B is again double (0"·4) but needs a larger telescope.
Zeta Aquarii	4·4, 4·6	2·6	291	Becoming more difficult.
Gamma Arietis	4·2, 4·4	8	000	Very easy.
Theta Aurigæ	2·7, 7·2	3	330	Stiff test for 3 in. OG.
Delta Boötis	3·2, 7·4	105	079	Fixed.
Epsilon Boötis	3·0, 6·3	2·8	340	Yellow, blue. Fine pair.
Kappa Boötis	5·1, 7·2	13	237	Easy.
Zeta Cancri	5·6, 6·1	5·6	082	
Iota Cancri	4·4, 6·5	31	307	Easy. Yellow, blue.
Alpha Canum Venat.	3·2, 5·7	20	228	Yellowish, bluish. Easy.
Alpha Capricorni	3·2, 4·2	376	291	Naked-eye pair. Alpha again double.
Eta Cassiopeiæ	3·7, 7·4	11	298	Creamy, bluish. Easy.
Beta Cephei	3·3, 8·0	14	250	
Delta Cephei	var, 7·5	41	192	Very easy.
Xi Cephei	4·7, 6·5	6	270	Reasonably easy.
Gamma Ceti	3·7, 6·2	3	300	Not too easy.
Zeta Coronæ Borealis	4·0, 4·9	6·3	304	
Delta Corvi	3·0, 8·5	24	212	
Beta Cygni	3·0, 5·3	35	055	Yellow, green. Glorious.
61 Cygni	5·3, 5·9	25	150	
Gamma Delphini	4·0, 5·0	10	265	Yellow, greenish. Easy.
Nu Draconis	4·6, 4·6	62	312	Naked-eye pair.
Alpha Geminorum	2·0, 2·8	2	151	Castor. Becoming easier.
Delta Geminorum	3·2, 8·2	6·5	120	
Alpha Herculis	var, 6·1	4·5	110	Red, green.
Delta Herculis	3·0, 7·5	11	208	Optical double.
Zeta Herculis	3·0, 6·5	1·4	300	Fine, rapid binary.
Gamma Leonis	2·6, 3·8	4·3	121	Binary; period 400 years.
Alpha Lyræ	0·0, 10·5	60	180	Vega. Optical; B faint.
Epsilon Lyræ	4·6, 6·3	3	005	Quadruple. Both pairs separable in 3 in. OG.
	4·9, 5·2	2·3	111	
Zeta Lyræ	4·2, 5·5	44	150	Fixed. Easy double.
Beta Orionis	0·1, 6·7	9·5	205	Rigel. Can be split with 3 in.
Iota Orionis	3·2, 7·3	11	140	

Name	*Magnitudes*	*Separation,"*	*Position angle, deg.*	*Remarks*
Theta Orionis	6·0, 7·0 7·5, 8·0			The famous Trapezium in M.42.
Sigma Orionis	4·0, 7·0 7·5, 10·0	11·1 12·9	236 085	Quadruple. D is rather faint in small apertures.
Zeta Orionis	1·9, 5·0	3	160	
Eta Persei	4·0, 8·5	8·5	300	Yellow, bluish.
Alpha Piscium	4·3, 5·3	1·9	291	
Alpha Scorpii	0·9, 6·8	3	275	Antares. Red, green.
Nu Scorpii	4·2, 6·5	42	336	
Theta Serpentis	4·1, 4·1	23	103	Very easy.
Alpha Tauri	0·8, 11·2	130	032	Aldebaran. Wide, but B is very faint in small telescopes.
Zeta Ursæ Majoris	2·3, 4·2	14·5	150	Mizar. Very easy. Naked eye pair with Alcor.
Alpha Ursæ Minoris	2·0, 9·0	18·3	217	Polaris. Can be seen with 3 in.
Gamma Virginis	3·6, 3·7	4·8	305	Binary; period 180 yrs. Closing.
Theta Virginis	4·0, 9·0	7	340	Not too easy.

Some Interesting Clusters and Nebulae

Object	R.A.		Dec.		*Remarks*
	h	*m*	°	′	
M.31 Andromedæ	00	40·7	+41	05	Great Galaxy, visible to naked eye.
H.VIII 78 Cassiopeiæ	00	41·3	+61	36	Fine cluster, between Gamma and Kappa Cassiopeiæ.
M.33 Trianguli	01	31·8	+30	28	Spiral. Difficult with small apertures.
H.VI 33–4 Persei	02	18·3	+56	59	Double cluster; Sword-handle.
M.1 Tauri	05	32·3	+22	00	Crab Nebula, near Zeta Tauri.
M.42 Orionis	05	33·4	−05	24	Great Nebula. Contains the famous Trapezium, Theta Orionis.
M.35 Geminorum	06	06·5	+24	21	Open cluster near Eta Geminorum.
H.VII 2 Monocerotis	06	30·7	+04	53	Open cluster, just visible to naked eye.
M.41 Canis Majoris	06	45·5	−20	42	Open cluster, just visible to naked eye.
M.44 Cancri	08	38	+20	07	Præsepe. Open cluster near Delta Cancri. Visible to naked eye.
M.97 Ursæ Majoris	11	12·6	+55	13	Owl Nebula, diameter 3′. Planetary.
M.3 Canum Venaticorum	13	40·6	+28	34	Bright globular.
M.80 Scorpionis	16	14·9	−22	53	Globular, between Antares and Beta Scorpionis.
M.4 Scorpionis	16	21·5	−26	26	Open cluster close to Antares.
M.13 Herculis	16	40	+36	31	Globular. Just visible to naked eye.
M.92 Herculis	17	16·1	+43	11	Globular. Between Iota and Eta Herculis.
M.7 Scorpionis	17	51·6	−34	48	Fine open cluster. Very low in England.
M.23 Sagittarii	17	54·8	−19	01	Open cluster nearly 50′ in diameter.
H.VI 37 Draconis	17	58·6	+66	38	Bright planetary.
M.8 Sagittarii	18	01·4	−24	23	Lagoon Nebula. Gaseous. Just visible with naked eye.
NGC 6572 Ophiuchi	18	10·9	+06	50	Bright planetary, between Beta Ophiuch. and Zeta Aquilæ.
M.17 Sagittarii	18	18·8	−16	12	Omega Nebula. Gaseous. Large and bright.
M.11 Scuti	18	49·0	−06	19	Wild Duck. Bright open cluster.
M.57 Lyræ	18	52·6	+32	59	Ring Nebula. Brightest of planetaries.
M.27 Vulpeculæ	19	58·1	+22	37	Dumb-bell Nebula, near Gamma Sagittæ.
H.IV 1 Aquarii	21	02·1	−11	31	Bright planetary near Nu Aquarii.
M.15 Pegasi	21	28·3	+12	01	Bright globular, near Epsilon Pegasi.
M.39 Cygni	21	31·0	+48	17	Open cluster between Deneb and Alpha Lacertæ. Well seen with low powers.

PART FOUR

Miscellaneous

Some Recent Books

Encyclopedia of Astronomy, by G. E. Satterthwaite (Hamlyn, 1970). A very full 'astronomical dictionary', with over 500 pages; under the circumstances the price, £6·30, is by no means excessive. It is invaluable as a reference book.

Astronomy, by D. H. Menzel (Thames and Hudson, London 1971). Also priced at £6·30. This is a popular work, lavishly illustrated, and highly recommended.

The Amateur Astronomer and his Telescope, by Günter D. Roth (Faber & Faber, London 1971). A book by a well-known German amateur, well translated by A. L. Helm. It deals largely with telescopes and their adjustment.

Exploring the Planets, by Iain Nicolson (Hamlyn, London 1970). A popular introduction, aimed at younger readers. The text is very good, and the price – only 30p – very attractive!

The Amateur Astronomer, by Patrick Moore (Lutterworth, 1971). This is the seventh edition; the section dealing with the southern sky has been added, and all the familiar features of the book have been retained and brought up to date.

Astronomy and Space, a new periodical (David Charles, 65p quarterly). Contains articles, notes and news, reviews, letters and 'stars of the month'.

Our Contributors

W. M. BAXTER, Director of the Solar Section of the British Astronomical Association, has his observatory at Acton, where he uses his 4-inch refractor to take the beautiful sunspot pictures which are known all over the world.

MARTIN COHEN, B.A., is a Cambridge graduate, who has specialized in infrared astronomy. At present he is in the United States carrying out research into this field. As he so rightly says, infrared astronomy is a young science, and Mr Cohen has already made very valuable contributions to it.

C. A. CROSS, B.SC., is a mathematician who is particularly interested in the Moon, and has made many contributions to lunar and planetary studies, both observational and theoretical. He is also well known as a lecturer. His home is in Northwich, Cheshire, where he has lived for many years.

HOWARD MILES, M.SC., is Director of the Artificial Satellite Section of the British Astronomical Association, and Lecturer in Mathematics at the Lanchester College of Technology, Coventry. He, too, is one of our most regular and valued contributors.

IAIN NICOLSON, M.SC., is Lecturer in Astronomy at the Hatfield Polytechnic; he is a graduate of St Andrews University. His main astronomical interests are stellar, and he has undertaken considerable original research into interstellar matter. He has also lectured extensively, and is known for his appearances on B.B.C. Television.

COLIN A. RONAN, M.Sc., a regular *Yearbook* contributor, was for many years on the secretariat of the Royal Society, but now works independently from his home in Suffolk. He was formerly Director of the Historical Section of the British Astronomical Association and is now the Association's Editor. He is a Member of the International Astronomical Union, and is the author of many books dealing with astronomy and the history of science.

F. R. SPRY lives at Selsey, in Sussex. He uses a 6-inch reflector for his observations, but is particularly interested in the practical matters of instrument and observatory construction. He is a member of the British Astronomical Association.

HENRY WILDEY, Curator of Instruments of the British Astronomical Association, is one of our best-known lens and mirror makers, and needs no introduction to anyone who is interested in astronomy. He lives in Hampstead, and is Curator of the Hampstead Public Observatory.

Astronomical Societies

The advantages of joining an astronomical society are obvious enough. Full information about national and local Societies was given in the 1966 *Yearbook*; a condensed list, suitably brought up to date, is given below.

Name	*Secretarial Address*	*Yearly Subscription* §=members under 18, or 'juniors'	*Meeting Time and Place*
British Astronomical Association	Burlington House, Piccadilly, London, W.1. (J. L. White)	£3·25 (§£2·50)	Burlington House, Piccadilly Last Wed. each month (Oct-June)
Irish Astronomical Society:			
Belfast Centre	35 Ardenvohr Road, Belfast (D. Beesley)	£1 (§50p)	Fortnightly, Queen's University, Belfast
Dublin Centre	St Fintan's Cottage, Carrickbrack Road, Sutton, County Dublin (F. Murphy)	£1 (§50p)	Fortnightly University College, Earlsfield Terrace, Dublin
Armagh Centre	The Royal School, Armagh (J. Perrott)	£1 (§25p)	Monthly The Planetarium, Armagh
North-West Centre	Magee University College, Londonderry (Professor W. J. Guthrie)		
Aberdeen and District Astronomical Society	14 Abbotshall Gardens, Cults, Aberdeen (W. P. Cooper)		Robert-Gordon's Institute of Technology St Andrew Street, Aberdeen
Altrincham and District Astronomical Society	10 Delamere Road, Gatley, Cheadle, Cheshire (Colin Henshaw)	25p	Park Road Library, Timperley 1st Friday of each month 7.30 p.m.
Aylesbury Astronomical Society	9 Elm Close, Butler's Cross, Aylesbury (N. Neale)	£1	As arranged
Birmingham Astronomical Society	17 Hannafore Road, Edgbaston, (W. E. Marsh)	£1 (§25p)	Birmingham and Midland Institute Monthly
Bridgwater Astronomical Society	8 Dunkery Road, Bridgwater, Somerset	50p	The Fountain Inn, Bridgwater, 1st Friday in each month
Brighton Astronomical Society	6 Old Shoreham Road, Hove 4, Sussex (Brigadier V. M. Papworth)		

Name	*Secretarial Address*	*Yearly Subscription* § = members under 18, or 'juniors'	*Meeting Time and Place*
Bristol Astronomical Society	34 Butterfield Close, Bristol BS10 5AZ (G. H. Woodman)	£2·50 (§52½p)	Royal Fort (Rm G44) Bristol University last Friday each month, Sept.-May
Caithness and Dounreay Astronomical Society	Room 31, Ormlie Lodge. Thurso, Scotland (Miss M. J. A. Clark)	£1	Fortnightly
Cambrian Astronomical Society	43 Heol Chappell, Whitchurch, Cardiff (G. Stokes)	75p (§37p)	Every 3rd week, 7.30 38 Park Place, Cardiff
Cambridge Astronomical Society	5 Haggis Gap, Fulbourn (S. R. Whistler)	£1·05 (§37½p)	7 Brooklands Avenue, Cambridge 2nd Mon. each month, Oct.–July
Chelmsford and District Astronomical Society	65 Longstomps Avenue, Chelmsford, Essex (J. N. Trompeter)		Civic Centre, Chelmsford Friday Nights
Chester Astronomical Society	37 Alwyn Gardens, Upton, Chester (A. Kemp)	£1(§50p)	St Andrews House, Newgate St., Chester Monthly
Chester Society of Natural Science, Literature and Art	26 Guy Lane, Waverton, nr Chester (Mrs N. Hoskyns)	—	Grosvenor Museum, Chester Fortnightly
Chesterfield Astronomical Society	Hilltop Cottage, Gallery Lane, Holymoorside, Chesterfield (Mrs R. C. Naylor)	£1 (§50p)	Barnett Observatory Newbold Each Friday
Clackmannanshire Astronomical Society	9 Deer Park, Sauchie, Alloa (J. Cluckie)	£1	St Mary's School, Alloa Monthly, 3rd Friday Sept.–May
Cleethorpes Astronomical Society	95 Sandringham Road, Cleethorpes, Lincolnshire (W. S. Cobley)	£1 (§50p)	Dolphin Hotel, Cleethorpes Monthly
Crawley Astronomical Society	Crawley College of Further Education, Sussex (F. D. Cooper)	37p	Crawley College of Further Education Monthly
Crayford Manor House Astronomical Society	Manor House Centre, Crayford, Kent (R. H. Chambers)	None	Manor House Centre, Crayford Monthly during term-time
Dundee Astronomical Society	4 Finlaggan Place, Dundee Scotland (D. Gavine)	50p (§25p)	Mill's Observatory Dundee Fortnightly in the winter
Eastbourne Astronomical Society	80 Ringwood Road, Eastbourne, Sussex (W. O. Tutt)	£1·05 (§52½p)	As arranged Monthly
East Lancashire Astronomical Society	95 Accrington Road, Blackburn (L. Willan)	£1 (§37½p)	Longridge Observatory Preston
Astronomical Society of Edinburgh	126 W. Saville Terrace, Edinburgh 9, Scotland (N. G. Matthew)	£1	Calton Hill Observatory, Edinburgh Monthly
Ewell Astronomical Society	11 Elmwood Drive Ewell, Surrey (L. J. Bentley)	£1 (§50p)	Ewell County Technical College, Reigate Road, Ewell, Surrey 1st Friday of each month

Name	*Secretarial Address*	*Yearly Subscription* § = members under 18, or 'juniors'	*Meeting Time and Place*
Fellowship of Junior Astronomers, Edinburgh	58 Ogilvie Terrace, Edinburgh 11, Scotland (Miss Edith McLean)	37½p	Calton Hill Observatory Edinburgh 2nd Sat. each month, Sept.–June
Fylde Astronomical Society	115 Abercrombie Road, Fleetwood, Lancs (P. P. Cuffe)	50p (§25p)	Nautical College, Fleetwood 1st Thursday of each month, Sept.–May inclusive
Astronomical Society of Glasgow	164 Mugdock Road, Milngavie, Glasgow, Scotland (N. M. Orr)	50p	Roy. Coll. Science and Tech., Glasgow 3rd Thur. each month, Sept.–April
Great Yarmouth Astronomical Society	38 Cobholm Road, Cobholm, Great Yarmouth, Norfolk (M. Poxon)	(To be announced)	(To be announced)
Herschel Society	35 Kendal Drive, Slough (C. Wise)	—	(To be announced)
Isle of Wight Astronomical Society	1 Hilltop Cottages, High Street, Freshwater, Isle of Wight (J. W. Feakins)	£1 (§50p)	Unitarian Church Hall, Newport, Isle of Wight Monthly
Junior Astronomical Society	58 Vaughan Gardens, Ilford, Essex	£1	Caxton Hall Quarterly
Leeds Astronomical Society	Maths. Dept., The University, Leeds 2 (B. L. Meek)	50p (§25p)	Leeds University Six annually
Leicester Astronomical Society	6 Walnut Grove, Glen Parva, Leicester (Mrs L. Withey)	£1·05 (37p)	Leicester Museum and Art Gallery Monthly
Lincoln Astronomical Society	344 Brant Road, Lincoln (P. Hammerton)	£1 (§25p)	Lincoln YMCA Hall 1st Tue. each month
Liverpool Astronomical Society	2 Greenacre Road, Woolton, Liverpool 25 (P. Leighton)	£1(§75 & 37½p)	City Museum, Liverpool Monthly
Loughton Astronomical Society	Aldersbrook House, Romford Road, Manor Park E12 5LN (D.E. Brede)	£1·50 (§£1)	Loughton Hall, Rectory Lane, Loughton, Essex Thursdays, 8 p.m.
Luton Astronomical Society	20 Bloomfield Avenue, Luton (S. J. Anderson)	£1	Last Friday each month
Maidenhead Astronomy Group	129 Fane Way, Maidenhead, Berkshire (S. A. H. Roper)	50p (§12½p)	Maidenhead Grammar School Once every 3 weeks
Manchester Astronomical Society	Cragside, Cliff Avenue, Summerseat, Bury (Alan Whittaker)	£1 (§50p)	Godlee Observatory, Manchester 1 Weekly
Mansfield and District Astronomical Society	14 Bonnington Crescent, Sherwood Estate, Nottingham (G. W. Shepherd)	50p (§25p)	Monks Precision Engineering Co., Mansfield Rd., Sutton-in-Ashfield Last Monday of each calendar month
Newcastle-on-Tyne Astronomical Society	30 Kew Gardens, Whitley Bay, Northumberland (G. E. Manville)	£1	Botany Lecture Theatre Newcastle University Monthly, Sept.–April

Name	*Secretarial Address*	*Yearly Subscription* §=members under 18, or 'juniors'	*Meeting Time and Place*
Newtonian Observatory Astronomical Society	101 Ardingly Drive, Goring-by-Sea, Worthing, Sussex (G. L. Boots)		
North Dorset Astronomical Society	The Pharmacy, Stalbridge, Dorset (F. Coward)	—	Charterhay, Stourton Caundle, Dorset Quarterly
Norwich Astronomical Society	The Manse, Back Lane, Wymondham, Norwich	£1(§50p)	The Observatory, Daniels Rd., Norwich 1st Tues. each month Sept.–May
Nottingham Astronomical Society	18 Naseby Close, Heathfield, Nottingham (C. Swift)	£1·25p	Monthly
Oxshott Astronomical Group	Norman Cottage, Pond Piece, Sheath Lane, Oxshott, Surrey (E. H. Noon)	50p	Oxshott Village Centre 1st Wed. each month Sept.–May
Paisley Astronomical Society	14 Cheviot Avenue, Barrhead, Glasgow (Mrs J. Holms)	£1 (§50p)	Coats Observatory, 49 Oakshaw Street, Paisley Monthly
Plymouth Astronomical Society	5 Woodside, Lipson, Plymouth (Lawrence Harris)		Plymouth College of Technology, Tavistock Road, Plymouth Monthly
Portsmouth Astronomical Group	52 Denbigh Drive, Fareham, Hampshire (S. W. Hackman)	£3	The Group Observatory
Preston and District Astronomical Society	35 Bispham Road, Carleton, Poulton-le-Fylde, Lancs (C. Lynch)	£1 (§25p)	Chamber of Commerce, 49a Fishergate, Preston 3rd Mon. each month Sept.–May
Salisbury Plain Astronomical Society	St George's Cottage, Orcheston, Salisbury, Wilts. (R. J. D. Nias)	50p (§25p)	St George's Rectory, Orcheston Quarterly
Slough Astronomical Society	The Elms, Odds Farm, Green Common Lane, Wooburn Common, High Wycombe, Bucks (E. Shilton)	£1	Monthly
Southampton Astronomical Society	13 Luccombe Place, Shirley, Southampton (F. G. H. Cunningham)	£1 (§50p)	Ploygon Hotel, Southampton 2nd Thur. each month Sept.–May
Southport Astronomical Society	43 Longford Road, Birkdale, Southport, Lancs. (H. Bloch)	75p	As arranged Monthly
South Shields Astronomical Society	Marine and Technical College, St George's Ave., South Shields, Co. Durham (H. Haysham)	£1 (37½p)	Marine and Technical College. Each Thursday, 7.30 p.m.
Stoke-on-Trent Astronomical Society	Sundale, Dunnocksfold Road, Alsager, Stoke (M. Pace)	75p	Cartwright House, Broad Street, Hanley Monthly
Swansea Astronomical Society	77 Craiglwyd Road, Cockett, Swansea (R. E. Roberts)	£1	As arranged
Thanet Astronomical Society for Youth	Woodlands, Fair Street, Broadstairs, Kent (Paul Sutherland)	25p	Hilderstone House, Broadstairs, Kent Monthly

Name	*Secretarial Address*	*Yearly Subscription* §=members under 18, or 'juniors'	*Meeting Time and Place*
Torbay Astronomical Society	4 Heath Rise, Brixham, Devon (Miss A. Longman)	75p (§25p)	Quay Tor Hotel, Scarborough Road, Torquay Monthly
Waltham Forest and District Junior Astronomy Club	24 Fulbourne Road, Walthamstow, London E17 (B. Crawford)	50p	24 Fulbourne Road, Walthamstow, London E17 Fortnightly (Mondays)
Warrington Astronomical Society	2 Dale Avenue, Appleton, Warrington (B. P. Rees)	£1	Central Library, Museum Street, Warrington, Lancs Monthly, Sept.–May
Warwickshire Astronomical Society	20 Humber Road, Coventry, Warwickshire (R. D. Wood)	£4	20 Humber Road, Coventry Each Tuesday
Wolverhampton Astronomical Society	Garwick, 8 Holme Mill, Fordhouses, Wolverhampton (M. Astley)	£1	38 Tettenhall Road, Wolverhampton Alternate Mon., Sept.–April
West of London Astronomical Society	46 Vista Way, Harrow, Middlesex HA3 OSL (P. Macdonald)	40p	Monthly, alternately at Ruislip and North Harrow 2nd Monday of the month (except August)
Wyvern Astronomical Society	2 Howcroft, Churchdown, Gloucester (A. F. Edwards)	75p (§25p)	Clubhouse, Churcham Last Friday of each month except Aug.
York Astronomical Society	97 Carr Lane, Acomb, York (R. Emmerson)	£1 (§25p)	As arranged Monthly, Sept.–May
Zenith Astronomical Society	4 Neptune House, Trafalgar Gardens, Burnley (A. Harvey)	£1 (§50p)	54 Cromwell Street, Burnley Monthly

It is possible that this list of local societies may not be quite complete. If any have been omitted, the secretaries concerned are invited to write to the Editor (c/o Messrs Sidgwick & Jackson (Publishers,) Ltd, 1 Tavistock Chambers, Bloomsbury Way, London WC1), so that the relevant notes may be included in the 1973 *Yearbook*.

1972 Yearbook of Astronomy

edited by

PATRICK MOORE

The 1972 Yearbook follows the popular pattern of previous editions, and amateur astronomers will find a wealth of information on every aspect of the stars and planets during 1972. Patrick Moore himself has contributed an article on southern stars, and has, as usual, reviewed recent astronomical developments. Dr Porter has also contributed his invaluable notes for the year, together with his star charts, and information about eclipses, occultations, comets and meteors.

This year's articles' section includes a study of Johannes Kepler, essays on fireballs, the far side of the Moon, modern infra-red astronomy, galaxies and quasars, the Newtonian Flat and its mounting, and an account of particular interest to amateur astronomers - of how to set up a run-off roof Observatory.

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